Master's degree thesis

LOG950 Logistics

Lean Procurement Planning in ETO Projects: A Case Study of Ulstein Verft AS

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Preface

This thesis has been the final stage of a Master's degree in Logistics at Molde University College and was written in the spring semester of 2019. The thesis has been a part of a project called SmartYard which is owned by Ulstein Group, led by Møreforskning, and which includes involvement of students.

We would like to thank our supervisor Steinar Kristoffersen for his valuable contribution through instructions, discussions and guidance throughout the entire process. His reflections and flexibility have been highly appreciated and insightful, especially considering his busy schedule as principle of the university, and we feel fortunate to have had him involved in this research. In addition, we are grateful of research scientist Kristina Kjersem at Møreforskning AS to have been our co-supervisor. We are appreciative of the opportunity to conduct the research and her continuous support and follow-ups.

Furthermore, we would like to thank our contact person at Ulstein Verft, Vidar Gjerdsbakk, for his help and availability in coordinating meetings, interviews, and quick response in email correspondence. Lastly, we want to thank all the respondents for taking their time and being so cooperative and accommodating in providing us insight of their industry and for the data collection.

Øyvind Magnussen

Andreas Ersland Aarra

Molde, 24.05.2019

Abstract

The purpose of this research is to contribute to Lean Construction and ETO literature. We have conducted a case study to investigate what challenges exist for a procurement department in an ETO organization using the concurrent engineering approach, and how the Last Planner System® (LPS) can improve planning of procurement activities. This is answered based on researching how the concurrent engineering approach impacts planning procurement activities in an ETO project, how the current planning structure of the case organization compare to LPS, and lastly, to what extent existing prerequisites for sound activities in production are applicable to procurement. New prerequisites for sound procurement activities are developed based on empirical findings. The methodological approach of the thesis is qualitative with an inductive reasoning. The concluding remarks of the thesis indicate that by fulfilling the prerequisites, LPS will improve planning procurement activities by improving teamwork between departments, ensuring reliable information flow, allowing root cause analyses, and by mitigating high levels of complexity through short-term planning.

Keywords: Procurement Planning, Engineer-To-Order, Concurrent Engineering, Lean Construction, Last Planner System®, Shipbuilding.

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CODP	Customer order decoupling point
ETO	Engineer-to-order
LPS	Last Planner System
DE	Detailed Engineering
RP	Research Problem
RQ	Research Question
US	Ulstein Shipyard
TPS	Toyota Production System
PDCA	Plan Do Check Act
LC	Lean Construction
CPM	Critical Path Method
SD	Sales Department
SPU	Strategic Purchasing Unit
RFQ	Request for Quotation
PPC	Percent Planned Complete
PO	Purchase Order

1.0 Introduction

Historically, Norway has been an important producer of all types of vessels and marine installations. In the 1970s, the competition from Eastern Asia intensified due to their low labor costs, and this forced Norwegian shipyards to scale down. In the 1990s, the focus was redirected to vessel conversion and repair work, in addition to an increasing specialization in serving offshore petroleum exploration and extraction activities. Since then, most of the larger vessels produced in Norway have been customized and technologically advanced offshore support vessels (Semini et al. 2018).

At the western coast of Norway, maritime organizations have for several decades operated in a maritime cluster environment. From 2004 to 2014, the cluster experienced substantial economic growth, mainly due to increasing oil prices and upswings in the offshore market. However, after 2008 the economic growth slowed down both due to decreasing oil prices, but also stagnation in productivity at the shipyards. Even though the offshore market is considered one of the main drivers for growth in the shipbuilding industry, the stagnation in productivity shows that other elements must be examined to explain why downswings have occurred in Norwegian shipbuilding industry (Mellbye, Nellemann, and Jakobsen 2016).

One of the main characteristics of Norwegian shipbuilding is that activities such as engineering, procurement, and production are performed concurrently (Halse, Kjersem, and Emblemsvåg 2014). This approach means that there is a continuous dialogue with the customer even after an order is placed and design of the vessel is determined. Changes in the specifications of components and design of the vessel can be made after the design phase has been initiated and may even occur far into the stages of detail engineering and production, and as a result, shipbuilding companies must be flexible and plan their operations to cope with the complexity (Vaagen, Kaut, and Wallace 2017).

Additionally, there are both internal and external stakeholders involved throughout the entire building process. This introduces challenges such as maintaining a reliable information flow between actors and keeping track of building progress due to a geographically spread supply chain with hulls typically being constructed in Eastern Europe. Operating in such complex conditions requires a planning system which is able to handle processes being performed concurrently, and which can assist in handling and mitigating the high level of complexity in the industry (Halse, Kjersem, and Emblemsvåg 2014).

The increasing global competition is also an important aspect which affects the development and profitability of Norwegian shipyards. From 2000 to 2005, approximately 20% of all vessels created worldwide were built in Norway, but numbers from 2011 to 2016 show that vessels built by Norwegian shipyards was reduced to 10%. Development and economic growth for the cluster in Møre and Romsdal county in the future therefore requires analyses and evaluation of current business processes, and it is essential to focus on innovative solutions and how to capitalize on the opportunities which arise from this (Mellbye, Nellemann, and Jakobsen 2016).

Today, Norwegian shipyards focus on outfitting vessels, while work with steel and hull structures is typically offshored to Eastern Europe because of significantly lower cost levels (Semini et al. 2018). Approximately 60-80% of value-added activities and equipment are procured from external stakeholders in shipbuilding projects. The complexity arising from involving multiple suppliers means that shipbuilding companies must focus on improving their ability to integrate suppliers for coordination of design, engineering, and production activities required to build a vessel (Held 2010). Further, the high number of stakeholders and the complexity of vessels in shipbuilding projects are examples of factors that may result in delays for project delivery. A strategy to prevent delays is to focus on detection of potential factors that may cause delays at early stages of projects, and to implement preventive measures in areas where managers are aware that problems may arise (Haji-Kazemi et al. 2015).

Traditional project management has for several decades been the preferred approach for project-based industries. However, managing and controlling projects by output measures and not having enough focus on delivering value to the customer by managing workflow have led to critique of the traditional management approach from a Lean Construction (LC) perspective (Koskela et al. 2002). LC is a concept within construction that builds on Lean Production principles with focus on reducing waste, increasing customer value, and continuous improvement (Dave et al. 2016).

As an alternative to traditional project management, LC proposes implementation of the Last Planner System®[1] (LPS), a production control system developed to supplement traditional project management that aims to increase planning and workflow reliability (Ballard, Hamzeh, and Tommelein 2007). The motivation for developing LPS was that traditional project management lacked a link between work structure and production control, which made it challenging to accomplish project objectives through preparation of tasks and completing tasks at the correct time (Ballard and Howell 2003b). Further, traditional project control objectives are to set cost and schedule targets, and secure that these targets are aligned with the project scope. The production control aspect provided by LPS assists organizations in performing activities according to plan, and develop a new approach on how to achieve targets (Ballard and Tommelein 2016). Literature on Lean, LC, and LPS is described in further detail in chapter 3.

1.1 Research Problem

This research is based on a single case study of a Norwegian shipbuilding company called Ulstein Shipyard AS (US), who began implementation of LPS in 2006 (Hoivind 2012, Gergova 2010). The case study is explained in detail in chapter 2, while the case organization is presented in chapter 4.

The motivation for this research is that US is currently experiencing challenges in planning procurement activities, and along with the research institute Møreforskning AS, we have found that thorough research on planning of procurement activities has not been performed. The purpose of this research is to investigate what challenges exist for a procurement department in an ETO organization using the concurrent engineering approach, and to analyze how these challenges affect the ability to plan procurement activities with LPS.
The research objective for this research is to answer the following research problem:

RP: ***How can LPS improve planning of procurement activities in companies using concurrent engineering?***

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[1] The Last Planner System ® is trademarked by the Lean Construction Institute. See www.leanconstruction.org
For simplicity, this trademark is not presented throughout the thesis.

To answer the research problem, three research questions (RQ) have been developed. These questions will be answered based on a literature review and empirical findings from interviews with US.

The first RQ aims to understand how the procurement department in US currently operates, and how the concurrent engineering approach affects their ability to plan procurement activities. We seek to understand what drives complexity and lead time in the industry, and the first RQ is as follows:

RQ1: ***"What is the impact of the concurrent engineering approach on planning procurement activities in ETO projects?"***

The second RQ aims to understand how the current work practice compares to the principles and rules in LPS, where identifying similarities and discrepancies is the objective. The second RQ is as follows:

RQ2: ***"How does the current planning structure in US compare to LPS?"***

The third RQ aims to develop prerequisites for sound[2] activities in procurement, which are based on existing prerequisites for production and empirical findings from US. The third RQ is as follows:

RQ3: ***"What are prerequisites for performing sound activities in a procurement department?"***

1.2 Important Empirical Findings

In this section, we present main empirical findings of the research and these are presented in detail in chapter 4.

There is significant dependency between departments due to the concurrent engineering approach. This means that the departments at US perform iterative processes, where the

[2] A sound activity is described as "a process where all prerequisites are in place and where the operation can be performed without any delay" (Bertelsen et al. 2006, 33)

procurement department, Detail Engineering (DE), and the production department are considerably dependent on information sharing to perform tasks.

The current situation at US is that the procurement department experiences challenges in planning activities, where main reasons are requested changes in design from customers, delays, lack of understanding of LPS, and that departments are isolated. Project meetings are arranged to cope with design changes that occur during projects, but empirical findings reveal that they do not create short-term plans to cope with the challenges that these changes introduce.

Each project at US is independent and has different priorities and routines. From a procurement perspective this means that the process of ordering equipment depends on either requested delivery dates in production, or the dates when technical documentation is required to verify compatibility of equipment. This is determined based on expected duration of projects.

The procurement process is characterized by several important elements, where an SFI and a makers list dictate which equipment must be ordered, and which suppliers may be used. Further, competitive bidding is used to make sure that specifications are satisfied, and this time-consuming process introduces long document cycles which can affect project lead times.

1.3 Structure of the Thesis

The first chapter of the thesis is the introduction, which contains the background and motivation of the thesis. The research problem with associated research questions and a brief overview of the literary basis for analysis and discussion is presented. The second chapter describes and justifies the methodological approach of the thesis. It includes a description of the research design, the case study approach, data collection, data analysis, and the quality of the research. The third chapter is the theoretical framework which presents the literary basis for the thesis. Main theory is the ETO production strategy and Lean. Within these main theories, we present project planning, the concurrent engineering approach, procurement in ETO, LC and the associated planning tool LPS.

The fourth chapter is two-folded, where the first part is a presentation of the case organization US. The second part is a presentation of empirical findings on the current planning structure and challenges US experience which are based on information from data collected primarily through interviews. The fifth chapter is an analysis of theoretical framework and empirical findings. Chapter six is a discussion of the analyses, where research questions and how our empirical findings compare to previous literature are discussed. Further, managerial implications are presented. Chapter seven is where we conclude the thesis by answering the RP. Finally, in chapter eight we present limitations of the study and encourage further research.

2.0 Methodology

In this chapter, the methodological approach of the research will be described and justified. First, the research design is defined as a combination of exploratory and descriptive. Second, the case study research is revealed with a following explanation of why a conduction of a single case study was selected. Third, the qualitative approach is accounted for with descriptions of how empirical data is collected. Then, a walkthrough of the data analysis follows before quality of the research completes the chapter.

2.1 Research Design

According to Yin (2003), research design is a logical plan for how empirical research is conducted. It involves a set of research questions to be answered, how data will be collected, and strategies for how the relevant data will be analyzed.

There are four alternative objectives of research design, and these are *exploratory*, *explanatory*, *descriptive* and *predictive* (Yin 2003, Ellram 1996). A categorization scheme is based on what the research question is focused on, and these are the familiar series of *who*, *what*, *where*, *how*, and *why*. There are two different types of *what,* where the first one is typically used for exploratory, survey, or archival research, and the second *what* is, along with *who* and *where,* typical for descriptive or predictive research. Lastly, *how* and *why* are typical for explanatory research. Developing hypotheses and propositions for further inquiry characterizes exploratory research, while descriptive research aims to describe the incidence or prevalence of a phenomenon (Yin 2003). Explanatory and predictive are not relevant strategies for this research.

We have conducted an exploratory-descriptive research. We consider RQ1 and RQ3 to be exploratory as they seek to gain insight and understanding of challenges in an industry, while RQ2 is considered to be descriptive because the objective is to investigate and describe similarities and differences between practice and a phenomenon.

2.2 Case Study Research

When researchers deliberately want to cover contextual conditions and believe that these conditions are highly relevant to the phenomenon to be studied, Yin (2003) recommends the use of case studies. He further defines a case study as the following:

“A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident” (Yin 2003, 13).

There are five research strategies to choose from, and these are experiment, survey, archival analysis, histories, and case study. There are three conditions for which one to choose, and these are based on the form of research question, if it requires control of behavioral events, and if the research focuses on contemporary events. A strength of case studies is the ability to handle a variety of different evidence and it is a preferred approach when behavior cannot be manipulated (Yin 2003).

We have used the case study strategy for our research. The case organization approached us via the research institute Møreforskning AS to perform research on their procurement department where the objective originally was to understand why they are unable to create plans and perform tasks according to plan. Archival analysis has been used to a little extent, while histories was not considered feasible as main research strategy to accomplish this objective because the current situation must be analyzed. Due to time limitations and inability to collect information on the current practice, experiment was not selected. Lastly, we could have collected data through using surveys, but decided not to because we wanted to understand perspectives through dialogue and have the ability to ask follow-up questions during interviews. Additionally, our lack of knowledge about the industry made us want to perform interviews to gain better insight in work structure and existing challenges.

In case studies, there is a distinction between *single*- and *multiple* case designs. A decision must be made between which of these two design types will be used prior to collecting data (Yin 2003). A single case study was chosen prior to beginning the research as the case organization reached out to the research institute Møreforskning AS, who collaborate with Molde University College and made the research available for students. As the case organization was the initiator of the research, it was natural to perform a single case study research on this respective organization. Time was also an influential factor as the research period was five months, and we therefore considered a single case study to be the best option for this research. In addition, concentrating on a single case study would allow us to collect proper evidence and information regarding the case organization, which to us makes the details more significant, but also considerably more interesting.

2.3 Data Collection

Research methodologies are classified based on the type of data and the type of analysis that is performed on the data. This can e.g. be empirical data collected for analysis from the real world, which is likely done via either surveys or case studies. The research methodology of using case studies to analyze empirical data is illustrated in Table 1 (Ellram 1996). As we have selected to conduct a case study to collect and analyze empirical data, a qualitative research methodology is considered suitable for our research. In the following section the qualitative research methodology is elaborated in detail.

Type of Data	Types of Analysis*: Primarily Quantitative	Types of Analysis*: Primarily Qualitative
Empirical	Survey data, secondary data, in conjunction with statistical analysis such as: factor analysis cluster analysis discriminant analysis	Case studies, participant observation, enthnography. Characterized by: limited statistical analysis, often non-parametric
Modeling	• simulation • linear programming • mathematical programming • decision analysis	• simulation • role playing

Table 1: Research Methodologies (Ellram 1996)

2.3.1 Qualitative Method

Data collected is distinguished between quantitative or qualitative, where quantitative data is data that can be connected to numeric values, while qualitative data on the other hand, is other data (Gripsrud, Olsson, and Silkoset 2016), likely in form of text (Larsen 2017). When collecting qualitative data, a flexible approach is suggested, and open interaction is encouraged if the collection method is through communication. Qualitative data is used for analytical descriptions and understanding relationships (Gripsrud, Olsson, and Silkoset 2016, 103, Ellram 1996).

2.3.2 Research Reasoning

Qualitative research further connects to inductive reasoning due to the researchers aim to explain questions that arise from observational elements (Williams 2007). Many of those who have a goal of developing new theories on the basis of their findings, tend to use the inductive approach (Larsen 2017). With the inductive approach, the researchers have an open research question instead of making any assumptions based on defined theory. The research question does also tend to change and develop during the research. Researchers further keep an open mind for any explanations and have not ruled anything out prior to the research. Additionally, relevant literature is related to the research findings (Leseth and Tellmann 2014).

During our research we have worked with different research problems. Our intention has consistently been to collect data from a procurement perspective, and to understand how planning of procurement activities are performed, but we have not worked with a defined research problem. Since LPS was implemented several years ago as a planning tool for the entire organization, our research problem has been adapted to fit this planning system. We approached the respondents in our interviews with open ended questions so that we could develop suitable research questions based on empirical findings, and we did not rule out anything prior to the research. There have been some different opportunities during the research, and discussions with our supervisor and co-supervisor to identify how the data could be utilized have been required to develop the final research problem.

2.3.3 Sources of Evidence

There are two types of data that can be collected, and these are primary- and secondary data. *Primary data* is data that is collected by the researchers who will conduct the analysis of the respective data, and the collection of data is described as a time-consuming and lengthy process (Bryman 2012). The second type of data, *secondary data*, is data collected by other researchers for analysis. It is cheaper to collect this kind of data, and it is typically a less time-consuming process (Bryman 2012, Johnston 2017). Therefore, both time and costs must be considered when deciding how to collect data (Bryman 2012).

Yin (2003) identifies six sources of evidence which are most commonly used when conducting case studies, and these are; *documentation*, *archival records*, *interviews*, *direct observation*, *participant-observation*, and *physical artifacts*. Evidence for case studies can be collected in different ways, and no single source of evidence has an advantage over any other source. The various sources are complementary to each other, and Yin (2003) recommends to use as many sources as possible to produce a good case study. Participant-observation has not been used to collect data for this case study research as we considered that it was not necessary for us to participate in any procurement work to gain a better understanding that would provide us with data that other methods could not. Physical artifacts are neither relevant because of the nature of the case study research.

Firstly, *documentation* can be letters, agendas, announcements, written reports, administrative documents, formal studies, or newspaper clippings. For case studies, documents are most importantly used to corroborate and augment evidence from other sources. They verify correct spellings, titles, or names of organizations that might be mentioned in interviews. In addition, they can provide inferences and reasoning such as e.g. distribution lists for a specific document (Yin 2003). US provided us with multiple documents to assist in understanding and for interpretation purposes. We have been provided an item requisition used in a project, this is available in Appendix 5. Additionally, annual reports have been used for information on US and industry news.

For case studies, *archival records* are another source of evidence that may be relevant, and this can for example be service records, organizational records, maps and charts, lists of names, survey data, or personal records. This source of evidence is typically used in conjunction with other sources of evidence. The importance of these records can range from only passing relevance, to being the objective of extensive retrieval and quantitative analysis (Yin 2003). In the collection of evidence in this research, organizational records were provided by US to assist in understanding the organizational structure of projects and to illustrate roles and responsibility of departments and workers. To visualize the structure of a specific ongoing project, a project structure overview was provided, and this is presented in chapter 4. Additionally, records of equipment specifications utilized in a completed project were lent to us in the research period for exemplification and to better understand how the procurement department use equipment specifications in their daily work.

Yin (2003) considers *interviews* to be the most important source of evidence for a case study, and these interviews are considered to be guided conversations rather than structured queries. Questions in the interview process must be developed in an unbiased manner and be open-ended, friendly, and non-threatening. Situationally, respondents may be asked to describe their own insight into certain occurrences, and this may be used as a basis for further inquiry. Also, participants can suggest other interview objects which they believe can provide something to the case study.

Larsen (2017) presents three types of interviews; structured, semi-structured and unstructured. For data collection in this research, semi-structured interviews with a flexible interview guide were chosen. In semi-structured interviews, the questions are formulated prior to performing the interview, but the order in which the questions are asked were flexible, and follow-up questions were asked if necessary. We formulated the interview guides, Appendices 1-4, prior to our visits, and the order of questions changed depending on the respondent's response. Some questions were also prioritized above others due to time limits.

Our data collection has mainly been through individual interviews during our visits at US, and this has required preparation and evaluation of how to proceed to extract information in a structured manner to use in our research. The interviews were recorded with consent from the respondents so we could transcribe the audio, and after both interviews, we wrote reports containing our immediate thoughts, before the recordings were transcribed to build a database of information and prepare for analyses.

Boyce and Neale (2006) state that the purpose of interviews is to explore views and impressions of people in an organization, and further explain that this method is good for understanding respondents' thoughts on a specific topic. We did not perform group interviews because our contact person at US scheduled the interviews to fit the respondents busy work schedule. However, we do not expect that the information would be significantly different if we had performed group interviews because their descriptions of plans and challenges were similar. We did neither use questionnaires due to the low number of respondents, and because we wanted answers verbally expressed. Focus groups and focus interviews have not been performed because of time limitation, but we did however spend time reflecting over the interview guides and make adjustments accordingly.

The level of detail in the information retrieved through interviews is the most advantageous compared to other sources of evidence, while bias, generalizability, time intensity, and training required to perform interviews are presented as pitfalls that must be avoided (Boyce and Neale 2006). Time intensity has been an influential factor in deciding to perform a single case study research and it has also been one of the reasons why we have not performed any training prior to conducting the research.

We conducted two semi-structured interviews during our three visits to US. The purpose of the first visit was to introduce ourselves and create a relationship with US and to share thoughts and ideas of the research. The interviews were conducted in the second and third visit. The respondents we interviewed were selected based on a discussion with our co-supervisor and contact person at US. We interviewed five people with connection to the procurement department who all contributed with valuable information to this research. All respondents provided equal amount of information, but in different areas of the procurement phase, and therefore we consider the respondents to be of equal importance.

During our visits to US, conversations with some of the respondents occurred outside of the recorded interviews. The information gathered during these conversations was mainly on development of the shipbuilding industry, and to understand their relationship with competing yards in the area. Some of the questions asked during interviews were also briefly discussed to make sure that answers were understood correctly.

The last source of evidence used for data collection was *direct observation*, and opportunities for making such observations can be made by visiting the case study “site”. Observations can range from formal to casual data collection activities. Formal occurrences can be made in meetings, sidewalk activities, factory work, classrooms etc. Casual data collection can be observations that are made during field visits, or when collecting data through other sources of evidence like interviews. Direct observations are typically useful in providing additional information on the research topic (Yin 2003). During the first visit to US, we were given a tour of the shipyard and provided with basic explanations of how a vessel is built and how the shipbuilding industry works. Additionally, during the interviews multiple respondents illustrated how their ERP-system works, how emails are used to communicate both internally and externally, and how both project- and procurement plans work.

2.4 Data Analysis

The information from the first interview gave us a better understanding of the shipbuilding industry and which practices exist throughout the organization, where our interest was especially how the procurement department was structured. In the second interview, we asked specific questions based on both the information provided in the first interview and dialogue with our supervisor.

When transcription of both interviews was completed, we discussed our impressions of the retrieved information and made comparisons to try and identify patterns. These comparisons were made to see if anyone changed their answers from the first interview, and additionally if there were significant discrepancies between the impressions of challenges for the respondents. The impressions of the purchasers on how well projects were planned and the cooperability across the organization throughout projects were of specific interest for us to understand the current situation. By identifying challenges and frequently occurring problems, the aim was to understand which prerequisites were required for the purchasers to perform the procurement process. Additionally, information from interviews provided us with their view on which challenges exist in the organization and how the departments cooperate.

The empirical findings presented in this research were developed through comparing information retrieved on three main areas; project plan, procurement plan, and the procurement process. Firstly, information was structured in chronological order according to these main areas, and then comparisons were made to identify similarities and differences in the information. We interpreted the comparisons and made descriptions which resulted in what we characterize as empirical findings. Lastly, we looked at our interpretations and compared these to see if the same challenges existed in the separate areas and combined these to present overall empirical findings for the procurement department.

2.5 Quality of the Research

To establish the quality of any empirical research, four tests are widely used, and whether the research is quantitative or qualitative, good research design requires construct, validity, internal validity, external validity, and reliability. However, internal validity is only of concern for explanatory or causal case studies, and is consequently irrelevant for case studies that are exploratory or descriptive in nature (Yin 2003, Ellram 1996). It is therefore not detailed any further in this research.

2.5.1 Construct Validity

According to Yin (2003), construct validity concerns establishing correct operational measures for the concepts being studied, and a test can be performed by the investigator. This can be done by selecting the specific types of changes that are to be studied and demonstrate that the selected measures of these changes do indeed reflect the specific type of change that have been selected. Further, both Yin (2003) and Ellram (1996) present three tactics to increase the construct validity of a case study. These are to use *multiple sources of evidence* because findings or conclusions are more likely to be more convincing and accurate, *establish a chain of evidence* to allow external observers to be able to trace the steps, and to let *key informants perform draft reviews of the case study.* Multiple sources of evidence have not been used for our data collection, and this may weaken the construct validity of the research. However, documentation, records and observations has been used to add insight, and email correspondence has been used to corroborate data collected and to clarify potential issues.

Establishing a chain of evidence is required for the reader of a research paper to be able to follow the entire case study and analysis (Ellram 1996). Throughout the period of conducting this research, both the supervisor and co-supervisor have been informed about the development of the it, including meetings and interviews with US, reports from visits at US, and they have additionally reviewed drafts and responded with feedback continuously. Due to a confidentiality agreement, there are restrictions to whom can review the thesis both ex ante and ex post of the hand-in. During the interviews, and later via email correspondence with a few respondents, control questions were asked for corroboration, and to ensure nothing was misconceived. A finished version of the thesis was sent to US for a review to ensure that information presented in the thesis is correct.

2.5.2 External Validity

External validity is a reflection of how accurate the research results represent the phenomenon that has been studied, and it establishes the degree to which the results can be generalized or applied to other phenomena. Lack of ability to generalize is considered to be the most significant criticism of case studies, but this can be addressed by replicating case studies and verifying patterns (Ellram 1996). The external validity of this case is limited until it is verified by replicating case studies. This is suggested later as a topic for future research. Yin (2003) also recognizes that external validity has been a barrier when performing case studies, and especially single cases due to their poor basis for generalization. He further claims that this is a common complaint, however, he emphasizes that no matter how large the set of case studies are, no case study or set of case studies are able to deal with this complaint. A solution to the complaint is to generalize findings to theory instead of generalizing to other case studies (Yin 2003).

We acknowledge that the external validity of this research is limited because it is a single case study. However, the empirical findings made in this research are generalized to literature opposed to other case studies, as we have not been able to identify other case studies on the same research topic, to improve the external validity as suggested by (Yin 2003). Literature presented in this research and other literature on the subject has been thoroughly reviewed in this research, and the interview guides have been based on existing and relevant literature to improve generalizability.

2.5.3 Reliability

Yin (2003) presents minimization of errors and biases in a study to be the goal of reliability. Further, a general approach to the issue of reliability is to make as many steps as operational as possible, and to conduct the research as if someone is looking over your shoulder. The research must be conducted in such a way that it can be audited, meaning that an auditor must be able to perform a reliability check and produce the same result if the same procedures were followed. Therefore, an important guideline when conducting case studies is to demonstrate the operations of the study, so the procedures of data collection can be repeated with the same results (Yin 2003). Our main focus during the research has not been to mitigate bias and ensure reliability. The research has been conducted with semi-structured questions, where follow-up questions to clarify information have been essential. Accordingly, if others try to replicate the study, we expect that information from respondents may not be equal to what we have found. We do however find it reasonable to assume that the information would point them in the same direction and that most of the empirical findings would be similar.

3.0 Theoretical Framework

In this chapter, literature required to answer the research problem is presented. Characteristics of the production approach Engineer-to-order (ETO) is described, before project planning, concurrent engineering, and procurement in ETO follow. Then, Lean, LC, and a benchmark of LPS are presented with existing prerequisites for sound activities in production.

3.1 Engineer-To-Order

Engineer-to-order (ETO) is a production approach characterized by low-volume production and a significant variety of unique parts which must be managed in complex projects. ETO production is typically found in industries such as construction, shipbuilding, and steel fabricators (Hicks, McGovern, and Earl 2000, Rauch, Dallasega, and Matt 2015, Vrijhoef and Koskela 2005). The four main production strategies make-to-stock, assemble-to-order, make-to-order, and engineer-to-order are illustrated in Figure 2 below.

What separates ETO from the other production approaches is that the customer order decoupling point (CODP) is located at the beginning of the design stage because each product is highly customized. This means that production is driven by customer orders instead of forecasts. Activities performed before the CODP are driven by forecasts, while activities performed after the CODP are driven by customer orders. Material flow is from the CODP connected to a specific customer order, and is considered the most important stock point where the process of a customer order begins (Gosling and Naim 2009, Olhager 2010, Weele 2014).

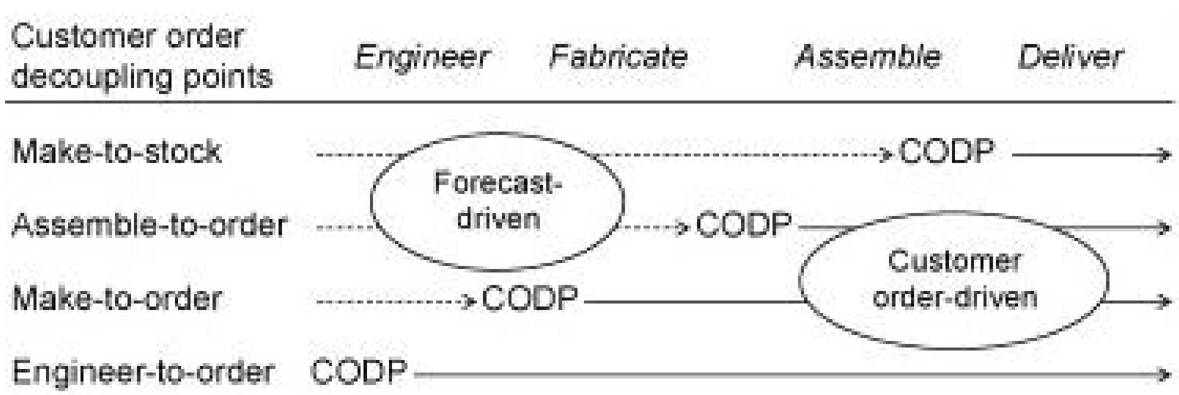

Figure 1: Production Strategies (Olhager 2010)

The product structure in ETO production strategy consists of a diversity of components which require multiple levels of assembly processes. Components can be either highly customized or standardized, and using highly customized components tend to increase costs, risks, and lead times of projects (Hicks, McGovern, and Earl 2000). Significant value can be gained by early identifying design alternatives and which activities have the most impact on the completion time of the project, because they typically carry the most uncertainty and require flexibility from the responsible organization (Vaagen, Kaut, and Wallace 2017).

3.1.1 Project Planning

In traditional project management, project planning typically contains a scope statement which is divided into a work breakdown structure. Planning is then completed by fulfilling minimum requirements such as allocating resources, presenting budgets, and determining the project schedule. The ultimate objective in traditional project management is to complete projects within time and budget, and satisfy customer requirements (Shenhar and Dvir 2007).

Understanding how to effectively utilize planning techniques is required to succeed with project management, and it is essential for organizations that everyone understand what objectives to accomplish. For complex projects, it is also essential to align the organizational structure with the project design, and ensure that prerequisites for sound resource allocation are fulfilled (Kerzner 2013). Further, operating in a project format simplifies planning (Wilson and I. Anell 2004), which is defined as a "continuous process of making entrepreneurial decisions with an eye to the future, and methodically organizing the effort needed to carry out these decisions" (Kerzner 2013, 508). Planning leads to better utilization of staff by distributing people to roles based on their skill level and experience, and by assigning responsibility to workers in an organization, concerns for top management is reduced (Wilson and I. Anell 2004).

In projects where complex products are produced, planning of procurement activities interact with how production and capacity is planned, which means that all planning must be considered at the same time (Alfieri, Tolio, and Urgo 2012). According to Aliza, Stephen, and Bambang (2011) planning procurement activities is essential in large and complex projects. They highlight that managers and organizations currently seem to underestimate the importance of planning these activities, as consequences of lacking a structured plan for procurement activities tend to show after project delivery.

3.1.2 Concurrent engineering

The concept of concurrent engineering has evolved from increasing product requirements and ability to respond to market changes (Anumba and Evbuomwan 1997). It is a concept where tasks are performed concurrently, meaning that stages are performed in parallel rather than in a determined sequence, and stakeholders involved in concurrent engineering processes have continuous access to design information (Demoly et al. 2011). The concurrent engineering approach speeds up completion time compared to using a sequential approach, but also requires organizations to analyze dependencies between the processes being performed at an early stage of projects. Moreover, concurrent engineering affects planning ability because the concept introduces new activities that interact with each other (Pieroni and Naveiro 2006).

Concurrent engineering aims to improve activities such as design, manufacturing, production, and marketing by focusing on increased product quality and reducing costs while removing non-value adding activities. It is an approach which requires organizations to understand downstream aspects of design and construction, how to remove non-value adding activities, and which emphasizes the need to work as a team to function in construction (Love and Gunasekaran 1997).

Figure 3 depicts how the concurrent approach works when implemented in an organization, and what how the approach reduces lead time compared to a sequential approach where each stage is completed before the next is initiated. The main activities included in the figure are engineering, procurement, and construction.

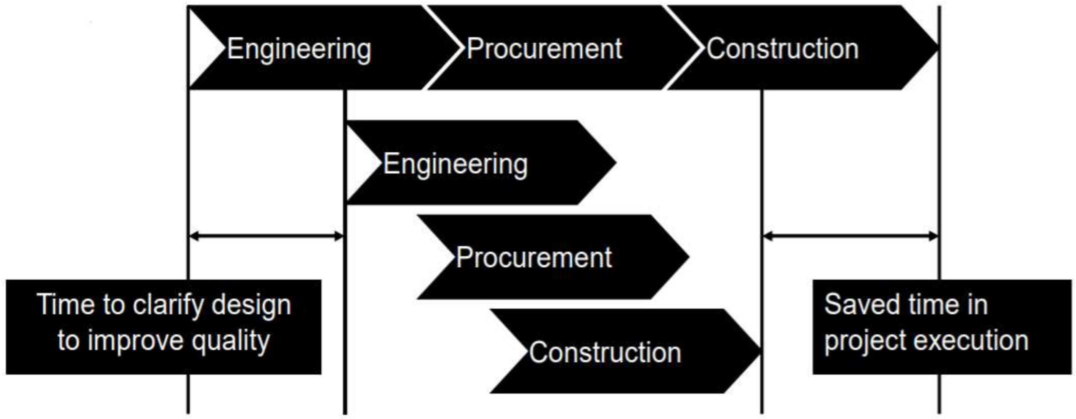

Figure 2: Sequential versus Concurrent EPC (Emblemsvåg 2017)

3.1.3 Procurement in ETO

Procurement includes all activities required to be performed to retrieve a product from a supplier to its destination. Purchasing is a part of procurement along with stores, transportation, inspections, and quality control and assurance. It is also a broader term than purchasing as it is based on total cost of ownership-thinking, which means that it relates to all costs the company will incur over the product life time (Weele 2014).

Weele (2014) further describes purchasing as activities aimed to determine the needs of customers, supplier selection, contract negotiations, order handling, monitoring and controlling orders, and lastly, following up on delivery and payment. His definition of purchasing is as follows:

"The management of the company's external resources in such a way that the supply of all goods, services, capabilities and knowledge which are necessary for running, maintaining and managing the company's primary and support activities is secured at the most favorable conditions" (Weele 2014, 8).

In the initial stages of a procurement process, the company must first decide whether to *make-or-buy*. It must be determined which products will be produced by the company itself, and which products will be contracted to external actors. The strategy chosen depends on the business model of the company. Purchasing products can be done based on either functional or technical specifications. *Functional* specifications describe the functionality of the product, meaning what purpose the product will serve. The advantages with this kind of specification is that suppliers are allowed to apply their expertise and knowledge into the product to develop a solution that satisfies the requirements. Alternatively, *technical* specifications describe the properties and characteristics of a product in greater detail. Detailed drawings and activity schedules are used to monitor what the supplier is doing. However, purchasing based on technical specifications can lead to over-specification, which in turn may result in increased costs without improved functionality of the product because of imposed requirements on product and the supplier (Hicks, McGovern, and Earl 2000, Weele 2014).

Hicks, McGovern, and Earl (2000) add that for ETO production, where cost and lead time are essential factors for competitive advantage, detailed technical specifications will affect these factors negatively. Thus, they suggest that functional specifications are the alternative to opt for in procurement.

When a customer approaches a manufacturer in construction for a project, the specifications of the PO is typically part of a scope-of-work description. The user or budget holder is responsible for specifying the requirements in the PO, and the purchasers are responsible for detailing the specifications in objective and supplier-neutral terms. What many construction organizations have done is to regulate this responsibility through the use of sign-off procedures, which in practice is a formal approval of purchases or supplier selection. This is meant to ensure that no misunderstandings occur in the consecutive stages of the procurement process, which will reduce the costs connected to changes of specifications. Another benefit of this are considerable reductions of the project's total engineering lead time (Weele 2014).

Moreover, for ETO organizations there is no stock as all purchases and orders of equipment are based on the specific customer order which is carried out for one specific customer, and the consequence of this is long lead times of the final product (Weele 2014). Elfving, Tommelein, and Ballard (2005) state in their case study research on competitive bidding in project-based production that procurement has significant impact on other delivery stages, such as design and manufacturing. They suggest that the industry has an incorrect perception of how significant the impact of procurement is and argue that the procurement method of competitive bidding may hamper reduction of total lead time of project delivery. Due to long lead times on equipment, too many decisions on design must be made early, and tend to be made based on vague understanding, incorrect information and assumptions, which forces departments to make suboptimal decisions, and leads to quality defects and rework. The pace and duration of a project tend to be determined based on the long product delivery times in project-based production like construction.

Weele (2014) describes competitive bidding as a situation where the buyer asks for bids from multiple suppliers to achieve a better deal, while Elfving, Tommelein, and Ballard (2005) state that competitive bidding has a significant impact on the total lead time and the number of changes that are made in the project period. It is a time-consuming process which increases the procurement lead time[3] of the delivery process indirectly through increasing the duration of the document cycle, opposed to increasing the time spent on procurement activities. The reason for this is the cycle of documents that is generated when sending Request for Quotations (RFQ) to multiple suppliers. Competitive bidding and the increased procurement lead time it generates is one of the reasons why upstream actors must commit early to design solutions and pursue large batch sizes. This leads to long design cycles, unreliability of design input, and long document cycles. Design is driven by technical documentation, and not the actual need for information and materials on the construction site (Elfving, Tommelein, and Ballard 2005).

What triggers changes in design after the engineering stage has begun in an ETO industry is long waiting times and the early commitments that are made by the procurement department when making purchases. Changes in design can in an ETO industry occur after the engineer stage has begun, and the consequences of such changes in design has a ripple effect that influence other actors in the supply chain (Elfving, Tommelein, and Ballard 2005). This is illustrated in Figure 4 below.

[3] Procurement lead time is defined as the time between preparation of requests for quotations and approval of drawings or placement of purchase order, whichever came later (Elfving, Tommelein, and Ballard 2005)

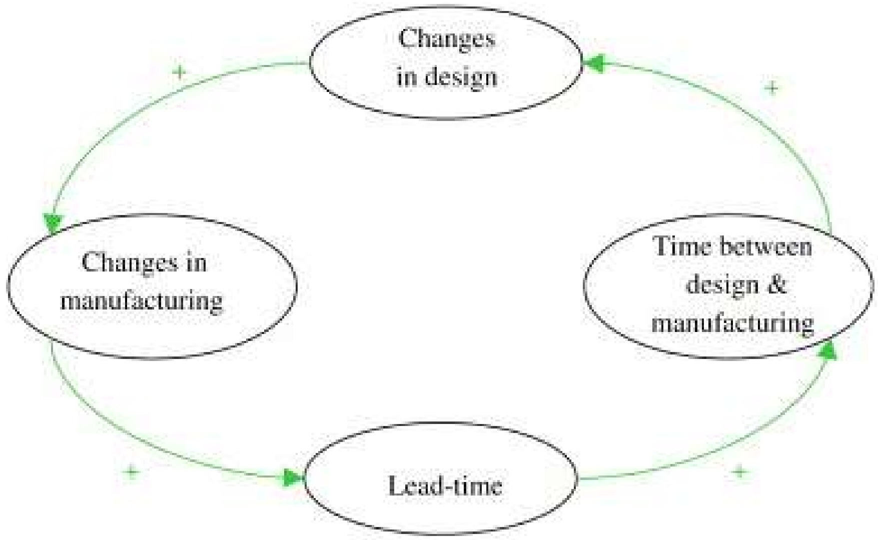

Figure 3:Consequential Cycle of Added Lead Time (Elfving, Tommelein, and Ballard 2005)

The changes itself requires the activity already performed concerning design to be performed once more. This creates a cyclical effect that in the end will ultimately lead to potentially making even more changes in design. The cyclical effect will be present no matter which circle is the trigger point of the cycle. Therefore, if there is a long lead time between design and manufacturing, it will influence the likelihood of changes in design to occur increases, which in turn increase leads to the likelihood of changes to be made in manufacturing, thus increasing the total lead time. As design solutions must be made early in the project, the decisions made are often made based on incomplete information and assumptions, which are not revealed until later in the project. For this reason, there is a risk of downstream actors in the supply chain to hedge against the uncertainty they receive from upstream actors by requiring "slack time" (Elfving, Tommelein, and Ballard 2005).

A significant portion of total lead time of purchases is spent waiting while other stakeholders are hurried and overwhelmed by a high level of workload, which is caused by large document cycles. The time spent waiting can even represent most of the total lead time. No preparation of manufacturing can take place before the necessary equipment has been ordered as there may be long lead times, or design drawings has not been received yet. This means that while one stakeholder is busy, others are waiting. Which consequently means that when an RFQ is prepared by a purchaser, other stakeholders are waiting, or when the supplier is preparing the quotations, other stakeholders are waiting. When one stakeholder is processing a task, that stakeholder is a bottleneck as the others ones are waiting (Elfving, Tommelein, and Ballard 2005).

3.2 Lean

The Toyota Production System (TPS), known as lean manufacturing, is a system that was developed by the car manufacturer Toyota to make them globally competitive. The system builds on eliminating waste in the manufacturing process and focusing on shortening the production flow to achieve high quality, low cost levels, and just-in-time deliveries. Waste is considered anything which do not add value to the product from the customer perspective, and the aim is to reduce such non-value adding activities as they significantly influence lead time (Liker and Lamb 2002).

TPS has since then been developed further to Lean Thinking, where the focus is on value-added flow and efficiency (Liker and Lamb 2002). Lean thinking is further described as a management philosophy with tools and techniques meant to reduce waste and increase quality, with identification of waste being the key principle. The difference between value-adding and non-value adding activities is unique for each product, because it requires each individual customer to specify what they consider to be value (Waterman and McCue 2012).

Examples of these techniques are PDCA and 5-whys. PDCA is short for the steps plan, do, check, act, and is a tool which enhances customer value through capturing and improving customer specifications. PDCA is used to identify problems, develop solutions, control that proposed improvements are incorporated, and use the output for decision making. It is an iterative process which leads to continuous improvement, as shown in Figure 5 below (Gidey et al. 2014). The 5-whys technique is a systematic problem solving technique where identifying the root cause of a problem is the objective through asking the question “why” as many times as required (Serrat 2017).

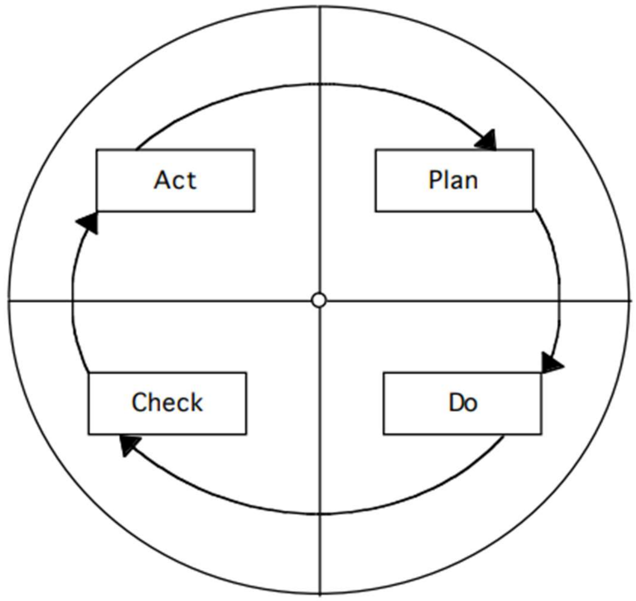

Figure 4: PDCA Cycle (Ballard and Howell 1997)

Further, Ansah, Sorooshian, and Mustafa (2016) imply that waste in projects is a result of existing project management models and strategies' inability to assist in delivering projects at the correct time. They propose LC as an approach for eliminating waste and ultimately reducing costs in the construction industry.

LC is a concept for construction management which contrasts traditional project management because the focus is on managing value throughout projects rather than management of schedules, cost, and output (Koskela et al. 2002). The concept is especially useful in complex projects where objectives go beyond eliminating waste and maximizing value. Applying specific techniques such as PDCA and 5-whys in a project delivery process introduces a new mindset where the focus is extended from evaluating trade-offs between time, cost and quality to identifying and solving problems and improving processes during weekly meetings (Halse, Kjersem, and Emblemsvåg 2014).

Implementation of LC tools can considerably improve performance in projects as LC aims to reduce waste in the workflow, which is not eliminated by conventional project management methods. Further, lean tools and techniques are essential for dealing with waste, and organizations must focus on aligning the goal of reducing waste and maximize value in the supply chain to achieve a reliable and predictable production system flow (Ansah, Sorooshian, and Mustafa 2016).

Ballard, Hamzeh, and Tommelein (2007) claim that LC can improve the performance of a production unit by up to 30 % or more by stabilizing workflow through reliable planning which shields the production unit from uncertainty that cannot be controlled. Further, they state that this has been proven in both design and construction for both small and large projects. Additionally, Ballard and Howell (1998) state that shielding production from upstream uncertainty requires activities to be defined, sound, sequenced, sized, and lastly that one must identify the root causes for activities that are not finished according to schedule.

Sarhan and Fox (2013) highlight three significant barriers to a successful implementation of LC, where the first one is not being adequately aware of lean and lacking understanding of lean principles. The second barrier is top management not being committed to the implementation, while the final barrier is characterized by issues or resistance in cultural and human attitude towards LC in an organization.

Utilizing LC tools and techniques requires sound activities (Bertelsen et al. 2006). An example of such a LC tool and its historic development, purpose, function and what benefits are possible to achieve if all prerequisites for sound activities are fulfilled is described in the following section.

3.2.1 Last Planner System®

In traditional project management where projects are sequential, the Critical Path Method (CPM) is commonly used, but this does not fit project-based industries. With CPM, planning is separated from performing tasks, plans are made early and contain many details, and these quickly become outdated and unrealistic in project-based production. The consequence of this is that workers ignore the plans and resort to ad-hoc solutions to ensure progress. Further, this leads to performing tasks without the correct conditions present, which in turn creates waste and backlog of tasks. This critique, along with the discovery of chronically low workflow reliability in construction projects, inspired to the development of the production control system LPS in the early 1990s (Ballard and Tommelein 2016, Kalsaas 2017, Kalsaas and Sacks 2011).

LPS is a production control system which is based on principles of lean philosophy and aims to increase the reliability of planning, and thereby improve the performance by adding the element of control to traditional project management. This is achieved by taking action at multiple levels of the planning system (Ballard, Hamzeh, and Tommelein 2007).

Improving workflow reliability of temporary and complex productions systems is the goal of LPS. In complex and dynamic environments, reliable plans cannot be made in detail before its execution, and this leads to uncertainties in both production itself and the feeding work- and information flows. This production control system ensures to establish continual learning of workers by measuring Percent Planned Completed (PPC), and using root cause analyses for processes and tasks that are not completed correctly in due time (Ballard 2000, Olano, Alarcón, and Rázuri 2009).

LPS will stabilize the entire project through improved workflow reliability (Ballard et al. 2016), and the purpose of LPS is to locate sources of variability, to initiate actions for corrections, and to monitor if these corrections work. It combines control and improvement to mitigate variability and the waste that is caused by it (Koskela 1999).

A key element of the LPS is to cooperate extensively with the ones executing the work, which may be suppliers and subsuppliers, as well as personnel and management. They coordinate their activities progressively more in detail when approaching the practical implementation (Kalsaas 2012). By carefully doing weekly planning and monitoring of the performances, the workflow becomes more stable. Such proactive planning allows the workflow to move across production units more frequently and at a superior rate (Ballard 2000, Bertelsen 2002).

The following list is a set of principles which function as a guide to both the thinking and action of projects, including the processes related to planning and execution of these processes. The principles of LPS are (Ballard and Tommelein 2016):

1. Keep all plans, at every level of detail, in public view at all times.
2. Keep master schedules at milestone level of detail.
3. Plan in greater detail as the start date for planned tasks approaches.
4. Produce plans collaboratively with those who are to do the work being planned.
5. Re-plan as necessary to adjust plan to the realities of the unfolding future.
6. Reveal and remove constraints on planned tasks as a team.

7. Improve workflow reliability to improve operational performance.
8. Do not start tasks that you should not or cannot complete. Commit to perform only those tasks that are properly defined, sound, sequenced and sized.
9. Make and secure reliable promises and speak up immediately should you lose confidence that you can keep your promises (as opposed to waiting as long as possible and hoping someone else speaks up first).
10. Learn from breakdowns.
11. Underload resources to increase reliability of work release.
12. Maintain workable backlog; a backlog of ready work (tasks ready to be executed) to buffer against capacity and time loss.

Moving from the principles to how the practical approach is, Figure 6 below is a comprehensive illustration of how LPS which presents the different phases and the content of each phase. The system is based on what should be done, what can be done, what will be done, and finally, what has been done. The first phase is what should be done, and this is specified in master- and phase schedules which describes what should be done and by whom the work should be done by. The second phase is the lookahead planning, and the purpose of this is to prepare scheduled tasks and make them ready so they can be performed when they are scheduled to be performed. The third phase is committing to the plans and highlighting what will be done. Commitment planning is selecting work packages that were made ready in the prior phase and expressing that the selected ones will be done in the scheduled period. In the last phase, what was scheduled to be done is measured compared to what was done. Failures are identified and analyzed with the purpose of countering them and preventing that they reoccur (Ballard and Tommelein 2016).

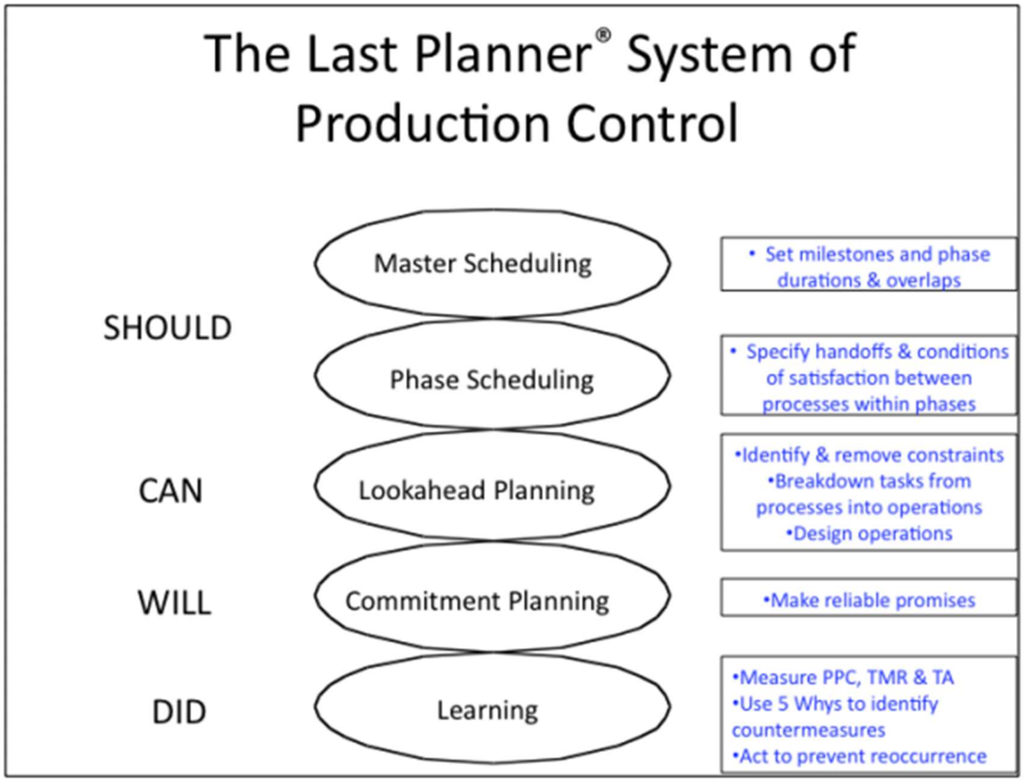

Figure 5: The LPS of Production Control (Ballard and Tommelein 2016)

In more detail, Figure 6 illustrates the different phases and content of each phase of LPS. Identifying what *should* be done is the first phase of LPS, and this is done in the master schedule and reverse phase scheduling (Ballard and Howell 2003b). In the master schedule, strategic planning of a project is done, major milestones are identified, and CPM is incorporated to determine the project duration. Further, phase scheduling generates a detailed schedule which evolves throughout a project as the master schedule is magnified into more detailed project components (Ballard and Howell 2003b, Ballard, Hamzeh, and Tommelein 2007).

Turning what should be done into what *can* be done by removing identified constraints in the make ready process is the second objective of LPS. Production planning begin by magnifying the detailed activities from the phase schedule and put them into the lookahead plan, which is a list of activities that are made ready to be executed for the six upcoming weeks. Constraint analysis is performed weekly to study threats to reliable workflow, responsibilities are identified, and tasks are made ready for what is ahead (Ballard, Hamzeh, and Tommelein 2007). If there is a constraint in an activity, a root cause analysis must be performed to identify the source of constraint and subsequently solve it proactively to hinder it from potentially having an impact on the schedule (Ballard and Howell 2003b).

Moreover, LPS tracks the commitments of what *will* be done and eventually what was done (*did*) (Ballard and Howell 2003b). What will be done is described in Weekly Work Plans, and these are the most detailed plans as it is done in a meeting shortly prior to performing the work and directly drives the production system. For example, if the execution of a plan begins on a Monday, the planning is preferable done the prior Friday. The participants in these meetings involve a meeting coordinator and all the last planners who relate to each other through prerequisites, shared resources, directives, or potential constraints. At this stage, the key is to only make quality assignments and reliable promises, thus the production unit avoid any uncertainty from upstream actors in the supply chain. The work assignment must be a measurable commitment so at the end of each week, assignments are reviewed for completeness as this will measure the planning reliability. Constraint analysis is an important part of this phase also and is done to investigate why failures occur and then acting on these failures as this is the basis of learning to eliminate failure (Ballard, Hamzeh, and Tommelein 2007).

This weekly planning and monitoring are done using look-ahead schedules that are created to make work packages ready, which in turn will control the flow of prerequisites on a long-term basis better. This contrasts with traditional production where work packages are pushed into the supply chain based on delivery- or completion date. Having work packages made ready allows the last planner to pull these work packages into the production process, but the last planner will only do this if the process is capable of being executed (Ballard 2000). In practice, the last planner may be different people, but those selected are typically responsible for the completion of individual assignments at the operational level (Ballard, Hamzeh, and Tommelein 2007, Salem et al. 2006).

The look-ahead schedules function as a coordination tool between the master schedule and the weekly work plan and contributes value to both production planning and control of complex projects (Ballard 2000). However, Aslesen and Bertelsen (2008) add the social perspective to the literature and argue that there are elements of LPS that have implications for social issues at the work site. The willingness to change among the workers may in general be challenging to overcome, and implementation of LPS is no exception. Examples of such changes are the introduction of a new hierarchical level of production preparations as the look-ahead process is established, the final decision maker changes as requirements from the foreman in production become commitments to the rest, and lastly, a shift in focus of production control which changes from issuing tasks to controlling the flows that links them together.

The last part of LPS focuses on learning from what has been done (did). To measure the reliability of the weekly planning, practitioners use PPC to assess the reliability of scheduled work (Ballard, Hamzeh, and Tommelein 2007, Olano, Alarcón, and Rázuri 2009). The measure is calculated based on what has been completed compared to what was scheduled to be completed and is calculated as a percentage and is typically measured at the end of each week. The weeks are typically also compared to each other to analyze patterns. Also when the week is finished, constraint analysis is performed to identify sources of constraints to learn why scheduled work was not completed, and to prevent the constraints to have an influence again (Ballard and Howell 2003b, Ballard and Tommelein 2016).

To implement LPS, Ballard and Tommelein (2016) stresses the importance of tailoring the means through which production is planned, executed, controlled improved to fit the type of work that is performed, but also the workers that perform it. The reason for this is the inherent complexity that exist in the project-based production as there are multiple stakeholders, different locations and alternating sourcing options. Determining which protocols the production control system should enable will depend on how much variability is allowed in the production system and the corresponding allocation of buffers. This includes the degree of detail level and frequency of planning, control and feedback, but also whether physical control is used, software control, human control, or a combination of the three.

3.2.2 Prerequisites for Sound Activities

The research literature presents two alternative sets of prerequisites that must exist to enable sound activities and allow for proper implementation of LPS. The first alternative is developed by Ballard and Howell (2003a), who have found three categories of constraints for construction tasks, i.e. directives, prerequisite work, and resources. The directives are e.g. design documents, specifications, and task assignments which provide guidance on which output to produce. Prerequisite work is the work that must be completed before an activity can begin, e.g. raw materials or work-in-progress, input of information for calculations, or decisions. The last constraint is resources, which concerns labor, instruments of labor or conditions in which labor is exercised. It can also be tools, equipment, or space, but it is neither materials nor information.

The second alternative is developed by Koskela (2000), who has identified seven preconditions that are similar to the three of (Ballard and Howell 2003a). The seven preconditions are illustrated in Figure 7 and are construction design (information), components and materials, crew, equipment, space, connecting works (previous work), and external conditions. The figure is based on information from (Koskela 2000), and is presented in (Bertelsen et al. 2007). These conditions must be fulfilled for any construction task to be sound, which (Ballard 2000) considers not being undertaken by delays, which is a significant matter with LPS.

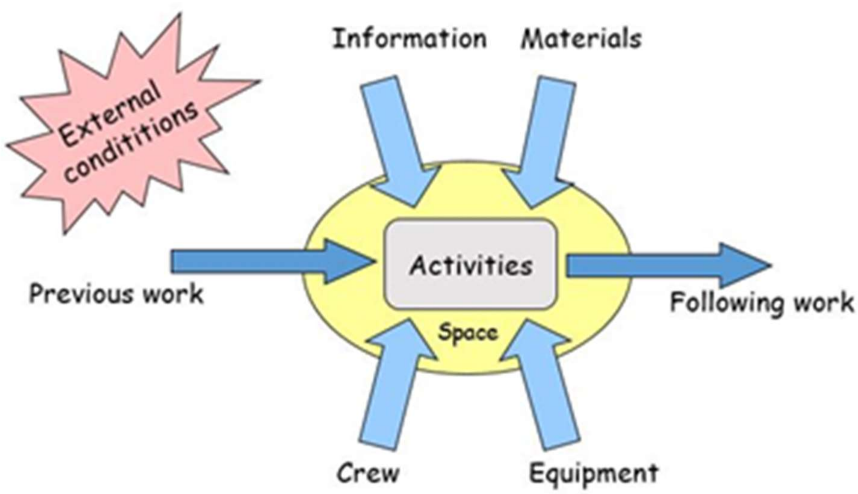

Figure 6: The Seven Preconditions for Sound Activities (Koskela 2000)

It is evident that the literature of Ballard and Howell (2003a) on prerequisites is more condensed opposed to the more fragmented seven prerequisites developed by (Koskela 2000), which can be scrutinized as a checking list. However, the two alternatives do share some similarities. In the category of directives by Ballard and Howell (2003a), content can be compared with construction design of Koskela (2000) as both contain information on design, specification, and task assignments. For prerequisite work, which include material, by (Ballard and Howell 2003a), the content is equivalent to the prerequisite of connecting work, components, and materials of (Koskela 2000). Lastly, the category of resources by

Ballard and Howell (2003a), the content is equivalent of workers, equipment, and space of (Koskela 2000).
The prerequisite that separates the two alternatives is the external conditions which Koskela (2000) includes in his literature. Examples of external conditions is weather, as extreme temperature, rain, snow, and wind may affect the production units that are not sheltered, or if it hinders tasks in any ways.

Ballard (1999) discusses the impact sound activities have on productivity in his research on workflow reliability and argues that productivity will increase if the activities that are performed are sound. When the design information is correct and updated, resources are available, workspace is allocated, and the requirements are clear, total labor time is represented by actually doing work opposed to looking for missing materials or switching between unfinished tasks.

Tribelsky and Sacks (2010) points at independent design and engineering teams to have a negative effect on the flow of information because of the high number of links that then will exist within a work process. Kjersem and Emblemsvåg (2014) exemplifies the concern of Tribelsky and Sacks (2010) with a subcontractor waiting for technical information from the technical coordinator who has requested certain equipment from the procurement department which in turn has ordered the equipment from a supplier. This sequential and disjointed flow of information affects the implementation of concurrent engineering, which is significantly dependent on satisfactory communication between the actors involved in a project.

Kalsaas (2013) and Emblemsvåg (2014) are less convinced of LPS. They argue that it must be developed further to handle advanced engineering design work, and that a better instrument is necessary to measure physical progression. In their respective research, they each propose solutions to improve LPS. Inspired from offshore drilling construction, Kalsaas (2013) propose Integrated Project Engineering Delivery System, while Emblemsvåg (2014) on the other hand is inspired by the shipbuilding industry and propose Lean Project Planning. Kjersem and Emblemsvåg (2014) considers these attempts of improvement as proof that LPS still needs adjusting to better cope with the challenges that concurrent engineering, 3D modelling, and dispersed design and engineering teams. Further, they point out that there still does not exist a satisfactory framework for planning of design and engineering activities.

3.3 From Theory to Empirical Findings

In this chapter, a theoretical framework and a literature review based on previous research has been presented. To answer our research questions, the production strategy ETO and characteristics such as project planning and COPD must be introduced. Further, concurrent engineering is included as the literary basis for RQ1. Additionally, because US has implemented LPS, literature on lean and LC is presented to provide context, and furthermore, a recent benchmark of LPS has been presented to indicate the current status of the planning system. Lean literature is mainly included to answer RQ2, and research on prerequisites for sound activities within LC is the literary basis required to answer RQ3.

With this research, we aim to contribute to LC literature by investigating an industry characterized by a high level of complexity. Because we have not been able to identify previous research on planning of procurement activities with LPS, we seek to contribute to this literature by mapping existing challenges and analyze their impact on ability to plan procurement activities. Additionally, the existing literature on prerequisites for sound activities in production have been used to develop new prerequisites for sound activities for a procurement department in combination with empirical findings.

4.0 Case Description and Empirical Findings

This chapter is two-folded, where the first part is a description of the case organization US, and the second part is a presentation of our empirical findings from data collection.

4.1 Case Description

The organization studied in this case study is US, a subsidiary to the holding company Ulstein Group ASA, which was originally founded in 1917 by the name Ulstein mek. Verksted. The group is family-owned and consists of multiple enterprises as depicted in Figure 8 below. This includes Design and Solutions, Power and Control systems, Shipbuilding, Shipping, and Global Sales. The headquarter is located at the western coast of Norway in Ulsteinvik and, in 2017 the company had 562 employees across subsidiaries in six countries. 2017 is in the annual report described as a challenging year where restructuring was necessary for US to increase competitiveness because of a considerable loss of investments in the petroleum industry. However, US has succeeded in agreeing contracts in new market segments such as exploration cruise, RoPax, and wind vessels (Ulstein 2019). US is highlighted with a circle in Figure 8, which present the organizational structure of the group.

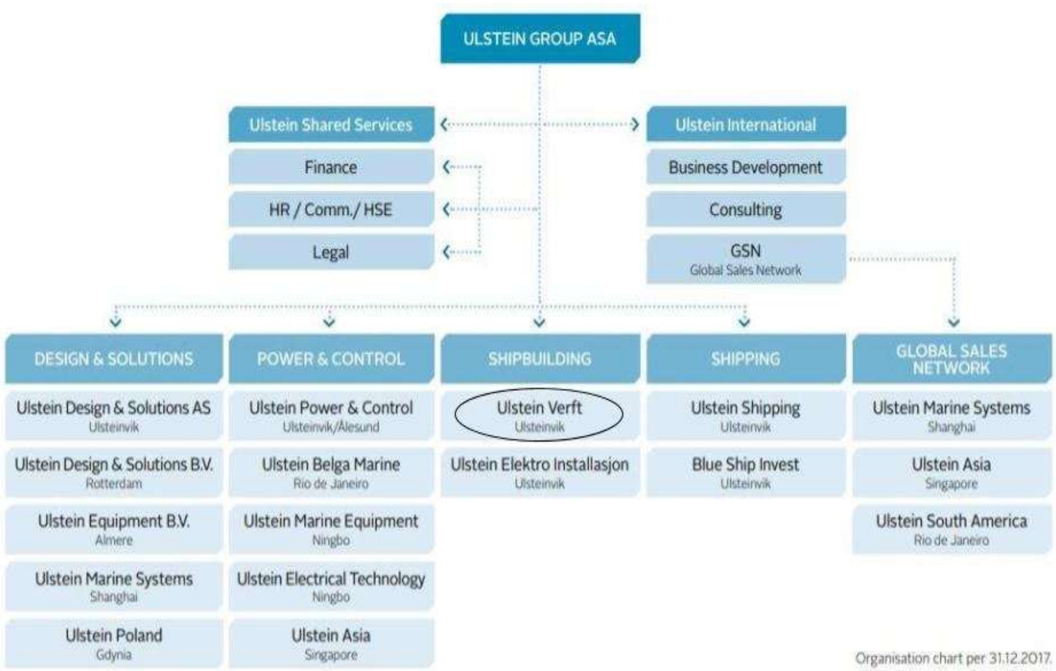

Figure 7: Organization Chart for Ulstein Group ASA per 31.12.2017 (Ulstein 2019)

4.2 Empirical Findings

In this section, our empirical findings are presented. First, we describe the project structure at US. Then, we describe the current planning procedures, before a walkthrough of the procurement process is presented. Lastly, we present overall challenges in the current practice from a procurement perspective.

4.2.1 Project Structure

US operate with a project-based production when building vessels, and each project is unique with the objective of building one specific vessel that is customized to fit customer requirements. A new project is launched when a customer contacts US through a shipowner, and dialogue between US and the customer continues throughout the project. Further, all projects have a defined structure that visualizes responsibilities for the different roles involved. Figure 9 below depicts the structure of a currently ongoing project for US, and it represents the typical project structure for US. However, slight changes in structure occur between different projects depending on what type of vessel US is building.

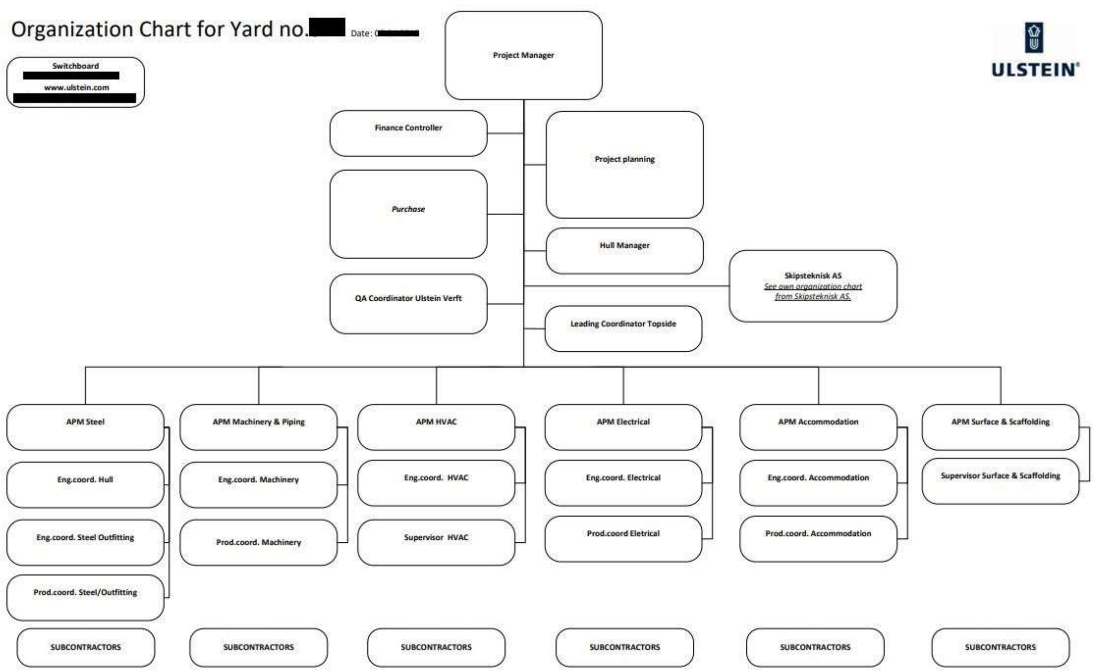

Figure 8: Project Structure

When a new project is launched, US first assign a project manager with the overall responsibility of the project. The Sales Department (SD) and a selected project planner are thereafter responsible for determining milestones and a schedule for the project participants through communication and negotiation with the customer. They create a project plan which contains this information, and this is distributed to everyone involved in the specific project. The project planner is responsible for updating milestone dates and register changes in the plan which affect those working in the project.

There are two different types of purchasers assigned for each project, one from the Strategic Purchasing Unit (SPU), and one project purchaser. SPU are responsible for negotiating contracts with suppliers who produce critical equipment with significant lead times in the initial stages of projects. They do not determine which offers to accept but include offers from different suppliers in a calculus which they discuss with the customer. When there is an agreement with the customer on choice of suppliers and equipment, two handover meetings are arranged. The first handover meeting is between SPU and the project purchaser to review the contracts and transfer responsibility from the SPU to the project purchasers. The second handover meeting is between project purchasers and the SD concerning budget limitations, and to inform which agreements have been made with the customer, i.e. at which stages the customer will transfer money to US during the project.

The bottom part of Figure 9 shows the production department and the Detailed Engineering department (DE). The production department consists of managers and foremen who are responsible for assembly, while DE is divided into several different disciplines. Each discipline has one technical coordinator who is responsible for determining functional specifications of equipment which is ordered within the respective discipline. The disciplines are steel, machinery and piping, HVAC (heating, ventilation, and air conditioning), electrical, accommodation, and surface and scaffolding. Aside from these coordinators, there are separate engineers responsible for drawing the vessel.

Two essential aspects in the project structure is the SFI structure and the makers list. The SFI structure is created in cooperation with the customer prior to the contract of a vessel is signed. It reflects the customer's preferences and recommendations from US on equipment required for building the vessel. Throughout projects the SFI is essential as it connects to the department plans and provide the workers of these departments with an overview of all equipment planned for the vessel. The equipment specifications are registered in detail during the project once exact specifications are determined.

The makers list is an overview of preferred suppliers to use for certain equipment which is composed by US in collaboration with the customer at an initial stage of projects. This is a list of suppliers that is approved in advance by the customer, and the purchasers can send RFQs to these suppliers to receive offers during the procurement process. For equipment where the customer does not have specific preferences on which supplier to use, US recommends a supplier to the customer and sends a request for approval to the customer before a purchase order (PO) is placed.

4.2.2 Project Planning

For all projects at US, a project plan is created as part of the contract with the customer ordering the vessel. The plan consists of milestones such as project order date, when to cut steel, towing of the vessel from the country where the hull is constructed, dock-time and outfitting in Norway, testing, and project delivery. It is initially a superficial plan of little use for project participants, but throughout the project it becomes progressively more detailed as department objectives are completed and strategic decisions are made by either the customer or US.

Milestone dates registered in the project plan are preliminary and are expected to be changed during the project when more information becomes available. However, the respondents explained that these dates are required to give an indication of the status of the project. Additionally, the milestones show the location of the vessel for everyone involved in the project, which is important because the hull is typically constructed in Eastern Europe. For the purchasers, these dates are essential because they reflect when the customer is supposed to transfer funds to US during the project, as this is done progressively after specific milestones are achieved.

The project plan is also the basis for separate department plans which are created in all projects for the involved departments. An example of such a plan is the procurement plan, which relies on both the SFI and scheduled delivery dates of equipment from the project plan.

The procurement plan is created when handover meetings are completed and responsibility of purchasing equipment is transferred to the project purchasers. The respondents described that the procurement plan is an extension of the project plan, and that it contains information specifically intended for the project purchasers.

Further, the procurement plan includes estimated lead times on the equipment required in the building process to generate proposed order dates. The lead times are calculated by the purchasers and are necessary to signal when DE must send item requisitions with functional specifications to ensure delivery of equipment at the correct time. Additionally, the purchasers can send reminders to DE if item requisitions are not received at the scheduled time. The purchasers will know which dates they need the item requisitions by using the procurement plan, which also informs them when to send reminders to DE if they are delayed. Further, when equipment is ordered, this is registered in the plan to confirm the purchase for other actors in the project, and for the purchasers to distinguish between what has been purchased and what is scheduled to be purchased.

There are two instances that influence when dates are determined in the procurement plan. The production department may need equipment by a certain date with an according lead time of this equipment of a month. However, DE must have technical documentation, which are drawings of the design equipment, by an earlier date compared to when assemble in production will take place as the equipment design must be controlled in a 3D model to control the compatibility of the equipment to fit the vessel. It is the date when DE need the drawings that determines when purchases are made because the purchasers do not receive drawings of the equipment design until they have made the purchase. To embody this description, a quote from one of the respondents regarding the purchase of winch follows.

"DE have requested to have a 3D model of the winch by March 22nd. By this time, I must have selected a supplier and placed an order to make sure the supplier have the time to send the drawing so that we receive it by March 22nd. We do not need the winch until maybe long after the summer for assemble, but we do need the technical documentation of it now."

When asked if adding slack time internally would be beneficial, a respondent explained it would not improve the flow of information between departments or make the planning of the procurement plan any easier. However, what would improve the information flow is to clearly define all processes across departments, to know when other processes are being performed across departments and determining areas of responsibility.

4.2.3 Procurement Process

The procurement process involves workers from both the procurement department, DE, and the production department. It is a time-consuming process which is dependent on information sharing and close collaboration between the departments involved. An illustration of the process is depicted in Figure 10 further below in this section.

The procurement process is initiated when DE sends an item requisition with functional specifications to the purchaser via email. The first task for the purchasers is to create an RFQ based on these specifications and send these to suppliers registered on the makers list. If the customer does not have a specific preference on suppliers for certain equipment, US select suppliers of their choosing and request approval from the customer before contacting them. RFQs are typically sent to four or five suppliers to ensure that quotations cover specifications and to lower the price. The procurement process proceeds equally regardless if a supplier is selected from the makers list or from US' preference.

Next, the purchaser must wait until suppliers respond with quotations on the equipment which has been requested, and when these are received an internal process at US begins. Firstly, the purchaser forwards the quotations received to DE, where their job is to ensure that the functional specifications are satisfied by the suppliers. US base purchases on the functionality of equipment, and not on significantly detailed technical specifications. The primary objective is to cover the customer's needs, and let the supplier present an offer that fulfils these functional requirements. Separate suppliers may therefore reply with different solutions that may or may not satisfy the requirements, but US will not get involved and dictate how the suppliers do their job. Because of this, US must evaluate how each quotation correspond to the requirements determined by the customer, and make sure that the quotations do indeed satisfy the minimum requirements of quantity, quality, and specifications.

An example of how the initial approach of the procurement process begins is provided by a respondent. If US want to purchase a ballast system, a purchaser request from the supplier that they need the system to handle e.g. 150 cubic meters per hour, and it is then in the hands of the supplier to offer a system that does just this. Four different suppliers may provide four different systems. One supplier may offer a system that has mechanical filtration, while others may offer a system that uses ultraviolet light. Dimensions may also be different on all the offered system, or equipment in general. The most significant factors depend on the project. Weight is an important factor when building a cruise vessel, and therefore lower weight will be valued more than lower price. In other situations, the lead time of equipment that will be procured is an increasingly significant factor the closer to delivery date it is. On windmill vessels, the project period is short, and therefore the lead time of equipment become a significantly important factor to consider.

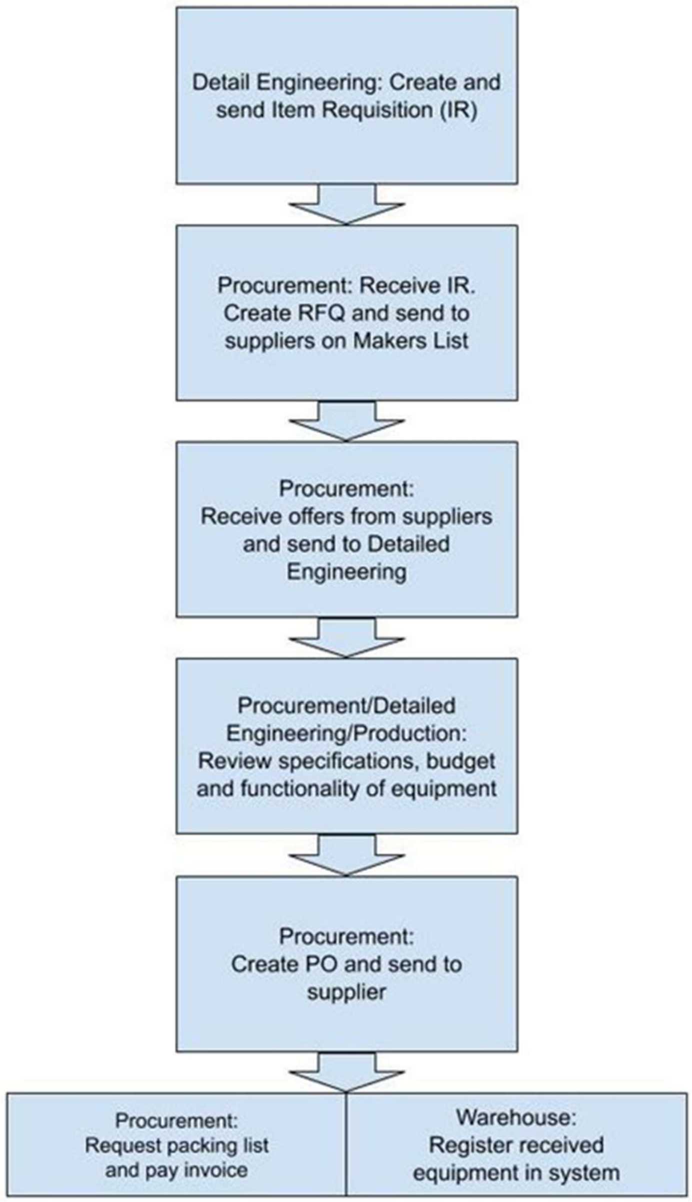

Figure 9: The Procurement Process

A discussion between the purchaser, DE, and the production department then follows on key elements such as price, total cost including and assemble, and functionality. Each department typically have different arguments on which offer to select, where purchasers desire the solution which is within budget, while DE and the production department may be more interested in the specifications. Through these discussions the aim is to select the supplier who offers a solution that most importantly satisfy the minimum requirements of functionality and specifications, while simultaneously minimize total costs, i.e. purchase price and total cost of assembly. The purchasers operate with a budget which limits how much US can pay for certain equipment, but the overall costs of purchase price, assembly, and satisfying functionality is more important than maintaining these budget limitations.

Further, a request is sent to the customer for approval of proposed suppliers. If the customer approves the selected supplier and specifications of the equipment, a technical coordinator from DE registers the approval in the procurement plan. The purchaser then proceeds to create a PO and sends this to the selected supplier. This marks the beginning of the most time-consuming process of procuring equipment, which is the negotiations between US, represented by the purchaser, and the supplier. Commercial terms such as price, functionality, delivery times, currency, services, guarantees etc. are negotiated until agreement is reached.

The purchasers then use the procurement plan as a tool to follow up on delivery of the ordered equipment and requests a packing list from the supplier prior to agreed delivery date. This is done to ensure that the warehouse receiving the equipment know what to expect and to simplify the process of collecting the equipment from the warehouse for assembly for the production department. When the warehouse has received the equipment, it is registered as received and notify the purchasers. The purchasers then proceed to pay the supplier to conclude the procurement process.

Procuring equipment can be done without interfering with others in the procurement department that are responsible for other projects, but to ensure that the optimal solutions are found, the purchasers may discuss and elaborate on previous experiences with suppliers. Getting advice and sharing experiences internally as a team is done to ensure that US do not enter negotiations with suppliers with bad reputations, or who may not have delivered according to agreed terms on earlier occasions.

4.2.4 Challenges

Descriptions of the challenges revealed in the data collection that hamper efficient workflow for the procurement department will be presented in this subsection. This subsection begins with challenges concerning internal dependency across departments, which connects with what the impact of changes has on US. Then, challenges that exist in the project plan and procurement plan follows respectively before how challenges in the warehouse affect the procurement department complete the subsection.

The procurement department is fully dependent on DE and this is considered the most significant challenge by the respondents is their dependency as DE provide the purchasers with item requisitions according to plan to perform their tasks. A respondent explained the following when discussing the item requisitions:

"*We are 100 % dependent on DE. If something is delayed in DE and we do not receive input from them, it does not matter how good we are at negotiating because we do not know the exact specifications of what we are purchasing*".

When there is no continuous flow of the item requisition because of delays, a bulk of them tend to accumulate in DE and this creates a bottleneck. Consequently, when this bulk later is sent to the purchaser, it relocates these problems which ultimately makes the procurement department the bottleneck. As each purchaser is responsible for individual projects, they have limited capacity, and therefore depend on a continuous flow of item requisitions from DE to avoid becoming a bottleneck. The relationship between the two departments is described as uncertain because of the high level of dependency that exists between them, and the currently unreliable information flow results in delays, which in turn causes the purchasers to often send reminders.

Communication among the three departments are divided into separate periods depending on the stage of the project. The respondents explained that they communicate mostly with DE at early stages of projects, and mostly with the production department at later stages. Another issue is that the production department is considered to become involved too late in projects, and since they provide the order dates to the project plan, which later are required to create the procurement plan, purchasers do not receive enough information at the beginning of projects. This hampers the purchaser's ability to deliver equipment intended for the yard creating the hull structure in the early stages of projects. According to the respondents, this challenge arises due to the current project structure combined with how the first milestones are usually scheduled too close to project launch.

The respondents revealed that a high number of changes in design usually occur throughout the building process. Because the customer must approve of suppliers that are not included in the makers list, and that specifications are in order before purchasers can send a PO, there is frequent communication between US and the customer. Thus, since purchases are made continuously throughout projects, the customer is heavily involved. Changes in design additionally have a branching effect on other orders. The most critical order is always prioritized before other orders.

Empirical findings reveal that changes in design occur often, and that changes occur either because the customer has requested it, or because equipment does not fit as anticipated. Respondents explained that changes are more likely to occur in the earlier stages of a project opposed to in the later stages. The reason for this is that the procurement plans lack details in the early stages. The procurement plans become progressively more detailed as the project evolves, and with the lack of details in the early stages, the likelihood of changes to occur at this stage is therefore higher. As the project evolves, more details are registered in the main schedule, and fewer changes are made.

When asked if changes of design are requested after equipment has been ordered and the production department is ready to begin assembly, a respondent revealed that it does, but the customer then must cover the costs connected to the changes that are made as the customer is the initiator of the change. The customer usually approaches US to investigate what the consequences are of making changes to equipment, and it then depends on type of equipment and how far into the process of procurement and assembly US is. It might be too late to make changes if equipment already is assembled and mounted on the vessel. The respondent followed up with an example concerning the possibilities of changing color of a crane:

"We may need to decline the request because the crane has already been assembled and mounted on the vessel, or the situation may be that it has not been painted in a color yet,

and then it is possible to change the color with no extra costs either. On the other hand, if it already is colored, they would need to cover the extra costs this creates".

The respondent continued explaining that that having the flexibility to do the changes will increase turnover, thus making providing US with incentives to make the change, however, if it will affect the delivery lead time of the vessel negatively, the customer will likely not be interested in making the change anyway.

Further, the respondents have different understandings of what the project plan provides. They all agreed that the project plan is rarely used because the information in the plan does not directly assist them in performing their tasks, but they have different descriptions of how detailed the plan is. These descriptions vary from a plan with few details affected by internal uncertainty at US because of vacation- and sick leave, to a detailed plan of little use due to project complexity and that the plan is changed frequently.

Similar to the project plan, the perceptions among the respondents are different in regard to how the procurement plan is used and what kind of overview it provides in projects. Currently, the procurement plan is mainly created to contain information, which signals when DE is supposed to send item requisitions with functional specifications. However, because the departments are isolated due to knowledge barriers, the workers do not comprehend how other department processes are performed.

Even though both a project plan and a more detailed procurement plan exist, the email inbox of each purchaser is described as what usually determine which tasks to perform on a day-to-day basis. This is due to inaccuracies in the procurement plan compared to the department plans of DE and production, and the fact that all departments are dependent on each other to complete tasks within the scheduled time. Since the procurement department represents US externally through negotiations with suppliers, the respondents emphasized that it is essential for them that item requisitions and evaluation of quotations are provided without delays.

US have several ongoing projects simultaneously, and respondents with fewer critical tasks in their respective projects assist with tasks across other projects which are approaching project delivery. By doing this, the tasks they were originally meant to be performed in their own projects are postponed, which in turn means that they will require assistance at a later stage in their own project. The result of this is increased time spent working on each project. Inability to maintain overview of time and responsibility is a challenge for US which interferes with how the project plan is set up. Respondents must be flexible and ready to step in on other projects while still manage their own tasks in a timely manner. Additionally, US typically receive financial penalties for every day the vessel that is being built is overdue.

During projects the project plan is used during weekly project meetings to review status on ongoing tasks, discuss responsibilities and determine when new equipment must be procured. The outcome of these weekly project meetings is a report which is sent to management to give them an overview and current status of projects, which means that the meetings do not contribute with details to the departments plans.

Further, the procurement plan is created with the intention of tasks being completed by one purchaser. However, assistance from other respondents is common when delivery date of the vessel is approaching, and this is emphasized by the different time frames on projects. In scenarios where there are no other project purchasers available to provide assistance on completing tasks, the purchasers must prioritize and structure the remaining tasks themselves to ensure completion before delivery. A challenge that arises with working individually at the late stages is to maintain an overview on what the status of DE and the production department is. Avoiding delays on delivery of the vessel is one of the most important aspects for US to maintain competitive advantage, and it is therefore essential that the procurement plan serves its purpose for the purchaser in understanding how to prioritize tasks.

The process of receiving equipment to the warehouse, and thereafter distributing the equipment to the production department has not been performed as desired in recent years. Instead of controlling that deliveries arrive correctly, US have in the past few years been forced to expect suppliers to deliver according to contracted terms due to lack of capacity. The respondents described that the consequence of this is that suppliers have taken advantage of the situation by reduced focus on delivering equipment at the correct time, with the correct quantity, and with the agreed quality.

Additionally, when a purchase is made from a supplier, the warehouse does not know which physical components are included in the equipment, and neither if the packing list attached to the delivery specifies these components in detail. The process of receiving goods and registering them in the system is therefore challenging and time consuming and may result in delays for the production department who will utilize the equipment.

Conversely, in projects where there is capacity to control deliveries, the challenge is that each supplier has their own unique packaging methods and delivery routines. This means that there are typically discrepancies between the packing lists received from the suppliers and the listed items in the PO, which makes process of registering the packing list to prepare the warehouse significantly time consuming. The respondents provided us with different descriptions of this entire process, where one respondent stated that US requests the packing list in advance to prepare the warehouse, while another explained that receiving the packing list would be a dream scenario. This indicates that the scenario differs for each project and depends on what equipment and which suppliers are used.

4.3 Summary

In this chapter, our case has been identified. A brief presentation of the case organization US, and our empirical findings during the research are presented. The information we have collected is from a procurement perspective, meaning that it reflects how five respondents experience current planning, their business processes, and what challenges exist. Due to the diversity in production of vessels, the respondents have provided insight from separate situations and stages of projects, and the sum of this information is what defined the structure of this chapter. Planning routines both on a project level and department level, and a detailed description of the procurement process have been described. Challenges in the overall structure have been emphasized to illustrate how the current practice affects performance and workflow. In the following chapter, the empirical findings are analyzed through applying literature.

5.0 Analysis

In this chapter, we present an analysis of empirical findings and the theoretical framework. First, a discussion on how the concurrent engineering approach and the procurement practice at US affect the ability to plan procurement activities is discussed. Second, a comparison of the current practice in US and the LPS structure is presented. The LPS structure and the twelve principles for guiding and planning presented by Ballard and Tommelein (2016) are then discussed to identify why the procurement department in US is experiencing challenges in both planning activities and performing these activities according to plan. Lastly, existing prerequisites for sound activities in production are applied to procurement.

5.1 Concurrent Engineering

Hicks, McGovern, and Earl (2000) and Weele (2014) express that it depends on the business model if an organization should make or buy the equipment and material needed to produce the product. Characteristics of a Norwegian shipyard like US that focus on outfitting and assembly of vessels will naturally choose to buy most equipment from external suppliers.

Our empirical findings reveal that US base purchases on functional specifications, thus allowing suppliers to apply their specific expertise on whatever equipment or service US is looking to purchase. If US was to not purchase equipment or services, it would need to produce themselves, and this would be outside the core competence of US. Instead, it purchases externally from someone who's core competence is production of specialized equipment for vessels, and this way it is able to acquire high quality equipment. It is also reasonable to assume that the suppliers have incentive to be competitive by having up to date technology for manufacturing which US do not have. US' business model relies on external actors, and in practice it functions as an assembler. This way it does not have to make significant investments to perform operations outside their area of expertise, and this has been the norm not only for US, but for most Norwegian shipyards in recent decades.

Further, operating with functional specifications will keep the costs lower than with technical specifications for US, and it also results in shorter lead times on equipment which is described as an important factor for competitive advantage by both Hicks, McGovern, and Earl (2000) and respondents in US. However, a consequence of purchasing based on functionality is that US is not aware of which components are included in the purchased equipment, and this often results in a mismatch between the packing list from suppliers and the PO sent by US. Because of this, a significant amount of time is spent on matching the packing list and PO when equipment is received at the warehouse, and thus time is spent on non-value adding activities instead of value-adding activities. An alternative to be considered for avoiding this time-consuming process is to make a modest increase in the level of specifications on equipment ordered. This must be done with the objective of simplifying the process of receiving goods at the warehouse, and not result in over-specified orders. Another alternative is to demand that all suppliers send a packing list before delivery to inform how the components are assembled which will give US time to prepare the process of receiving goods. This routine is currently not implemented in all projects but seems to be required for reducing time spent on non-value adding activities.

As US base purchases on functional specifications, more responsibility is put on the supplier to manufacture equipment and US relieves themselves of monitoring, thus putting more trust in the suppliers. It is reasonable to assume that a clear and understandable procurement procedure reduces complexity and simplifies planning for US. That would mean that purchases can be performed and register the lead times of equipment into the procurement plan and easily track the performance of suppliers.

The procurement department’s performance has a significant impact on the bottom line. The average purchase and stock item costs for projects at US make up a considerable amount of total costs in projects, and all the equipment required to build a vessel has to go through the procurement department because the purchasers have the knowledge required to negotiate contracts and commercial terms with suppliers. Even though most of the value-adding activities and equipment are procured from external actors, the procurement department also significantly impacts the other departments in US and total lead time of projects.

Due to the dependency that exists in US between the procurement department, DE and the production department, they all impact each other significantly. The concurrent engineering approach used at US means that business processes in all departments depend on each other, and that design changes from the customer will significantly increase complexity, which will make it more challenging to both plan and execute planned procurement activities.

Elfving, Tommelein, and Ballard (2005) and our empirical findings reveal that a change in design requested by the customer impacts tasks and plans for the procurement department. Due to the high level of dependency this further impacts activities in DE and the production department. Thus, changes in plans and scheduled activities must be made accordingly in DE and the production department as well, and US therefore share the impact of requested changes. If the consequences are delays in the lead time of equipment because of these design changes, and these delays influence US's ability to deliver the vessel within the agreed delivery date, the customer may not want to make the change anyway. Before US agree to any changes, it first investigate the impact of it on the lead time and explain the potential consequences before a final decision is made by the customer.

Depending on the changes requested by the customers, the purchasers must be flexible and understand how these changes affect their schedule for ordering equipment. However, it also requires that DE make adjustments and updates of the functional specifications, and that the production department registers when assembly of the new equipment is planned. The considerable dependency between departments emphasizes the challenges for planning, and furthermore implies that short term plans are essential to coordinate tasks among the departments to ensure project delivery within contracted terms. The dependency between departments which increases the significance of design changes seems to be a result of the flexibility which is offered through the concurrent engineering approach practiced at US.

Another driver of lead time suggested by Elfving, Tommelein, and Ballard (2005) is the procurement method called competitive bidding, and its ability to hamper efforts made to reduce the lead time. They described the negative effect that this method can have for an ETO organization, and there are similarities between this practice and our empirical findings at US as purchasers send RFQs to suppliers based on the makers list, which in general includes four or five suppliers. By doing this it receives different offers which are meant to cover the specifications, and additionally it gets competitive prices on the equipment. Depending on the project, having multiple offers to consider assists in getting the most advantageous agreement.

On the other hand, sending RFQs to multiple suppliers will generate multiple offers in return. This will increase the circulation of documents, and accordingly the handling time of these documents increases, which means that less time is spent on procurement tasks of other equipment. Therefore, the current practice of competitive bidding in US leads to competitive prices, but time spent on procuring equipment increases as each offer must be reviewed by the procurement department, DE, and the production department.

Circulation of documents is illustrated below in Figure 11. When a change is requested to made by the customer and accepted by US, it initiate a circulation that begin in DE (engineering) and is in practice similar to the procurement process with a discussion among the departments before an offer is selected which is illustrated in the right hand side of Figure 11. For each design change, a full circulation of documents flow among the departments and with the supplier, hence the outside circle in the figure below illustrating that the whole process must be performed again.

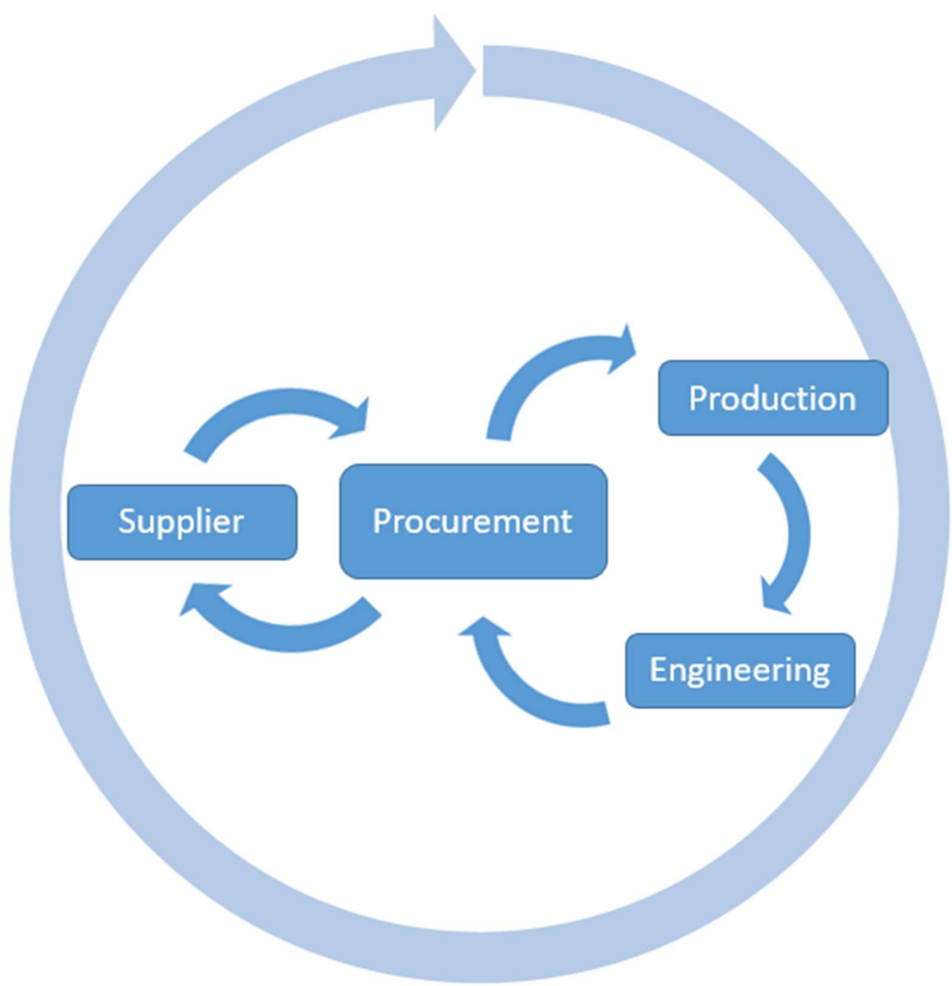

Figure 10: The Iterative Document Cycle

Potential changes in specifications, or in the production department if no supplier can satisfy the requirements may be needed. If the procurement lead times increases significantly, it may influence the total lead time of the project, which in turn can result in financial penalties from the customer. Therefore, it serves US best if it manages to simplify the process of evaluating offers from suppliers to reduce time spent on document handling.

What US have done to reduce the costs of design changes in later stages of projects is to use what the Weele (2014) refers to as sign off-procedures, and these are formal approvals of purchases or suppliers. The makers list is the equivalent procedure that US apply today for the approval of which suppliers to select when purchasing equipment. This ensures that the interests of the customer are kept, and it speeds up the operational procurement process. The purchasers do not have to spend considerable time in the supplier market to find suppliers as they quickly will know which suppliers to send their RFQs to as long as they have the list available. This results in both reduced costs and less time spent cycling documents, which in turn reduces time spent on non-value adding activities. This will reduce the complexity that exists and allow for more time to be spent to accurately make plans for present and future operations. If no offers are approved in the evaluation of functionality and price, new RFQs must be sent to new suppliers, and the iterative procurement process continues until an offer is accepted. If the supplier is not on the makers list, the procurement lead time will increase because US must have approval from the customer for selecting a supplier.

5.2 Comparison of Current Practice and LPS

When comparing the current work structure of US to LPS planning, our empirical findings suggest that the US work structure compares to several concepts from the LPS structure presented by (Ballard and Howell 2003b, Ballard and Tommelein 2016, Ballard, Hamzeh, and Tommelein 2007). There are similarities between the US project plans and the master plan from LPS, the department level plans and the LPS lookahead plans, and finally the weekly meetings which are arranged between the departments to discuss and plan tasks to be performed in the near future are comparable to the commitment planning part of LPS.

The project plan is created by the SD, who operate on a strategic level for US, and the plan matches the description of the master schedule in LPS by Ballard and Howell (2003b) and Ballard, Hamzeh, and Tommelein (2007) in several aspects. The SD at US interacts with the customer to initiate a project, while the milestones, sequence of activities, and duration of the entire project are in this process determined based on CPM. In addition, the project plan evolves throughout projects as more detailed information progressively becomes available. The project planner is responsible for updating changes in milestone dates during the building process, and it is common practice that changes are made due to the project circumstances. Further, because the project plan is the basis for the separate department plans and enable these plans to be created with detailed schedules, it matches how Ballard and Howell (2003b) and Ballard, Hamzeh, and Tommelein (2007) describe the phase scheduling in the LPS structure.

The lookahead plan from LPS and the department plans both share similarities but do however have some important differences. Firstly, a similarity is that the department plans provide information on tasks and activities in more detail than the master schedule. However, the main difference from the lookahead plan in LPS is that department plans do not provide information on when the tasks can be executed, and they do not explicitly include guidelines for when to make tasks ready. The department plans are updated when a preceding activity is completed, which means that purchasers must wait for confirmation before they can initiate their process.

The complex relationship between the procurement department and DE makes utilizing the lookahead plan challenging, because the procurement department are fully dependent on information from DE to begin the procurement process. The purchasers can view the procurement plan to see when the production department need the delivery of equipment, and accordingly when they must send the RFQ, but there is no guarantee for them that the preceding task is completed as scheduled. Further, root cause analyses are not performed to remove constraints continuously, they are conversely identified when tasks are performed. Additionally, lack of capacity prevents their ability to remove these constraints by using PDCA or five whys, which means that US currently fail to accomplish the process of turning tasks which should be done into what can be done as described by (Ballard, Hamzeh, and Tommelein 2007).

US arrange weekly project meetings, where the outcome is a report of the meeting which is sent to the management for them to review progress made in the project. Empirical findings indicate that this report is not used by the workers after the meeting. The details in the project plan are discussed during the meetings, but no plan is created based on the exchanged information. The aim with these weekly meetings is to discuss potential changes in delivery dates on equipment, which activities must be prioritized across all departments, and if there are any delays that need to be clarified. The source that creates the delays must be identified through root cause analyses and be acted on to prevent them from occurring repetitively. Differently from the LPS structure, information from these meetings is not registered, and a measurement of PPC is not done to gain overview of why tasks have not been performed as planned.

Further, weekly work plans are not created from the project meetings, and this opposes the descriptions of LPS and the requirement of a weekly work plan. The project plan is the basis for the weekly meetings, while department plans seem to function between lookahead plans and weekly work plans. Even though there is a direct connection between the department plans and the project plan, there is no connection between the separate department plans. This means that the shortcut of operating with one department plan to cover the intention of lookahead plan and weekly work plan from LPS hinders cooperation and a reliable workflow on the operative level among the departments.

A significant challenge for US is how the plans based on the LPS structure are being utilized. For US to benefit from the LPS structure and take advantage of their current practice, the workers must understand which framework they are operating with, and how the system works. The twelve principles presented by Ballard and Tommelein (2016) are guidelines for planning, and both workers and management at US must understand and apply these principles to benefit from the production control system and to achieve a reliable workflow in projects. An analysis of how these twelve principles compare to the practice of US is presented in the following section.

Compared to the first principle, US have all plans available for all project participants throughout projects. Even workers who are not directly assigned to a respective project have access in case they are required to assist in performing activities to achieve the project objectives, and project plans are kept at a milestone level of detail. However, even with plans available at all times, there seems to be little incentive for the purchasers to view and make use of the project plan. The impressions of the purchasers indicate that there are no defined routines on how the plan is supposed to be utilized, and moreover, that the plan is likely not equal for all projects. The only plan that can be used is the procurement plan, which can be interpreted as a mix between the lookahead- and weekly work plan. This indicates that the purchasers do not benefit from the LPS in its entirety, but rather parts of the system.

Based on the second principle, planning tasks in greater detail is not done when getting closer to performing them, and an example from the current practice is that the purchasers cannot communicate with external suppliers before functional specifications are prepared. That said, they can structure RFQs and prepare for negotiations on commercial aspects, but these preparations depend on what kind of equipment is required. Additionally, they are in general of little significance as they are not as time consuming as the rest of the procurement process. The lack of preparation on tasks imply that there is a lack of understanding of LPS in the organization. The consequence of this is that workers in all departments do not seem to understand the importance of completing tasks on time. For the purchasers, the consequence is emphasized as they are left waiting if item requisitions are not sent according to schedule.

For the third principle, the project plan is created by the SD, with input from DE and the production department. The purchasers are not involved, which means that the principle of collaboration with everyone meant to use the plan is not fulfilled in the current practice. However, the purchasers are responsible for creating the procurement plan which reflects some of the information in the project plan, but the same issue of lacking involvement by DE occurs here, because DE registers information in the procurement plan throughout projects. Moreover, the only one who utilizes the procurement plan continuously is the assigned purchaser for the respective project, and the lack of collaboration between departments means that problems are not made visible until they occur.

In terms of the fourth principle, department plans for US are automatically updated through changes in the project plan, i.e. change of date for towing a vessel is transmitted to those who perform processes related to the location of the vessel. Changes made in other department plans are conversely not automatically registered in the procurement plan, which means that plans are not adjusted to realities of the unfolding future as the principle requires.

For the fifth principle, there is currently little focus on resolving constraints to enhance performance due to lacking capacity. The constraints which affect tasks for the purchasers are related to uncertainty in delivery times from suppliers and dependency on other departments and given the current situation of unreliable workflow due to capacity issues, fulfilling principle number six and perform planning as a team is challenging. This is also the case for working on improving the workflow reliability, whereas all workers seem determined to perform their own tasks at the best of their capability, while trusting that other tasks are completed as expected.

Based on the seventh principle, the information flow between departments is currently unreliable, and delays frequently occur without being communicated of varying reasons. An example is that extensive workloads makes prioritization of tasks essential, and as a result the workers may not be aware that certain tasks have not been completed within the correct time. The purchasers implied that they too can be delayed in replying to requests from other departments, which indicates that this problem is common for all departments. A challenge is currently that workers seem to not speak up once they realize that work cannot be performed as promised. An example is how the warehouse management process which the purchasers are involved in creates confusion for the production department. The purchasers have promised to purchaser equipment but are unaware if the warehouse will register the equipment to make extraction of the equipment simple for the production department. Because of this uncertainty, they are unable to speak up and tell the production department that there may be delays.

Compared to the principle number eight, empirical findings indicate that tasks are indeed initiated without ensuring that they are prepared, which means that the principle of committing to defined, sound, sequenced, and sized tasks is not fulfilled. The mindset seems to be focused towards initiating tasks as each department pleases, without consideration of how this may affect or depend on others. This is a result of the unreliable workflow, and for purchasers the consequence is that defining tasks to be performed is not possible. Thus, they must perform tasks which are initiated elsewhere in the organization based on their prioritization.

Learning from breakdowns and handling consequences of actions and decisions is principle number ten, and this is currently a gradual process that US are working on. The current status is that constraints are being identified, but what remains is to perform root cause analyses and implement countermeasures.

Due to the currently high number of projects at US, underloading workers to increase reliability of work release is not prioritized, which is principle eleven. Lack of capacity is currently a significant challenge that forces US to continuously adapt and re-allocate resources to ensure delivery of vessels at the correct time. Maintaining a workable backlog, which is principle number twelve, seems to currently represent a dream scenario as the current situation is accelerating backlog rather managing it. The empirical findings emphasized that a corresponding challenge for the purchasers due to lack of capacity is that DE becomes a bottleneck. This means that uncertainty occur for the purchasers on how many tasks they can expect, and when these tasks will arrive.

This section has illustrated that there are both differences and similarities between the current structure at US and the LPS structure. Based on the challenges US experience, the following section presents an analysis of the applicability of prerequisites for sound activities in production to procurement. New prerequisites for sound activities in procurement are developed with the purpose of contributing to literature on what we have found to be required for organizations operating in complex environments to plan procurement activities.

5.3 Prerequisites for Sound Activities

Koskela (2000) and Ballard and Howell (2003a) suggest two alternatives to identify which prerequisites must be fulfilled to perform sound activities. In the following section, we apply existing prerequisites for production which have been presented by Koskela (2000) and Ballard and Howell (2003a) to procurement.

Previous work, information, materials, resources, equipment, space, following work, external conditions are presented as prerequisites for sound activities in production by (Koskela 2000, Ballard and Howell 2003a). However, these prerequisites do not take into account the uncertainty in other departments and therefore do not ensure that the organization as a whole perform only sound activities. When applying these prerequisites to the procurement department in this research, we find that only some of them are feasible. Previous work must be completed and defining following work is required both in a production department and for procurement, but we consider these prerequisites to be mandatory rather than prerequisites.

Availability of raw materials or work in progress, space, equipment, and external conditions are prerequisites for production of a vessel on-site. However, our empirical findings indicate that these are not prerequisites to perform sound procurement activities. Arguments can be made that space and equipment are prerequisites in procurement, but we consider office space and computers to be of significantly less importance than a dock and machines for cutting steel which are needed in production. Moreover, external conditions such as weather impacts the ability to plan production activities, but purchasers are not affected by this.

The remaining prerequisites information and resources are according to our empirical findings applicable for procurement activities, however some changes are required to make them compatible. The production department requires information from the procurement department on delivery of equipment, information on compatibility of equipment in the vessel from DE, and information for when to begin assembly from the SD. For resources, workers with knowledge on components and equipment such as electricians and plumbers are required. The content of these prerequisites is different for the procurement department due to the difference in tasks performed, and therefore we have developed new prerequisites specifically for the procurement department. These are presented in the following chapter.

6.0 Discussion

In this chapter, a summary of our analysis is first presented. Second, our RQs are presented and answered. A brief comparison of previous research to our empirical findings is presented in the third section, while managerial are presented to complete the chapter.

6.1 Summary

The concurrent engineering approach leads to increased flexibility for customers, which generates complexity for US. As the design of a vessel may change during projects because of the flexibility, equipment required for assembly changes accordingly, and the procurement department is then fully dependent on DE to create new functional specifications. The iterative procurement process which includes all the operative departments becomes increasingly complex by each change made by the customer, and original plans made for the purchasers change accordingly. This emphasizes the need for short-term plans based on weekly project meetings to continuously coordinate ongoing tasks and determine objectives for the near future.

Dependency between departments combined with the competitive bidding practice for supplier selection are two essential elements which affect project lead time and significantly influence workflow. Our empirical findings confirm that by practicing competitive bidding, complexity increases due to increasing document cycles and interaction between the departments. The need for customer approval on which supplier to select and the internal evaluations of functional specifications and total costs further make this a considerably time-consuming process.

Empirical findings indicate that departments are isolated due to knowledge barriers and the need for workers who are specialized within their field of work. This means that there are only a few people who are able to perform critical tasks such as supplier negotiations and preparing and evaluating specifications on equipment. This isolation results in what we perceive as a lack of understanding on a complete picture of the building process, which leads to unreliable workflow.

US operate with a planning structure that partially correspond to the LPS structure. Our empirical findings imply that there are several differences in the structure, where analyses of constraints and focus on implementing preventive measures to improve decision making are examples of tasks that are not performed. The underlying challenge with effectively utilizing LPS for US seems to be that workers are not taught how to use the system, and accordingly how it is meant to assist in planning and creating a reliable workflow throughout projects.

Lastly, we have proposed that prerequisites to perform sound activities in a production department are not applicable for a procurement department, and therefore new prerequisites must be developed.

6.2 Research Questions

RQ1: ***"What is the impact of the concurrent engineering approach on planning procurement activities in ETO projects?"***

Our research suggests that the concurrent engineering approach that US practice makes it challenging to plan procurement activities both short-term and long-term. The flexibility from using concurrent engineering allows customers to make changes continuously throughout projects. A negative consequence of providing customers with this flexibility is the internal impact that design changes have on processes. The changes affect the procurement department, DE, and the production department as these departments are heavily dependent on each other. This leads to changes in the project plan, and since the procurement plan is based on information in the project plan, this ultimately changes the procurement plan as well. As a result, purchasers must perform new processes according to changed information which means that their plan must be revised. Additionally, the complexity of design changes increases progressively during projects.

Further, concurrent engineering can result in bottlenecks because the number of tasks increases. According to our empirical findings, DE becomes a bottleneck because of design changes from a procurement perspective, because it is the only actor with the required technical knowledge to determine functional specifications in item requisitions that are needed to initiate the procurement process. The purchasers must in these situations wait until item requisitions are received, and this makes them work reactively rather than proactively according to plan.

Contrary to a traditional production strategy approach where processes are performed sequentially, processes are iterative when concurrent engineering is used. This requires a significant amount of communication between the departments compared to the sequential approach. As a result, dependency on information sharing and that plans are updated according to this information, increases.

Lastly, concurrent engineering leads to a significant number of additional documents that must cycle between the departments of US and suppliers each time a change in design is requested by a customer. This is an iterative process which involves multiple stakeholders at the shipyard and avoiding increased lead times of projects requires cooperation. All departments must update their plans according to customer changes, which emphasizes that the complexity generated from concurrent engineering significantly impacts the ability to plan procurement activities.

RQ2: ***"How does the current planning structure in US compare to LPS?"***

There are some similarities and several differences in the work structure at US compared to how LPS is presented in literature. Empirical findings from our research indicate that similarities are reflected by the implementation of LPS in 2006, while differences seem to be caused by the high levels of complexity in the industry.

US have a project plan which reflects the LPS master schedule, a mix of lookahead plans and weekly work plans in their current department plans, and weekly project meetings are arranged. However, a challenge with using this structure is that empirical findings suggest that workers do not understand the structure, and therefore tend to perform tasks based on experience opposed to how the plans indicate that they should be performed.

Moreover, there are several differences in the current practice and LPS, and the differences are lack of constraint analyses and focus on implementing countermeasures to prevent problems. Measuring PPC during weekly project meetings is currently not performed, and as a result US are made aware of constraints and problems during processes, rather than through teamwork where root causes are identified and analyzed. The lack of teamwork in project meetings are according to our empirical findings due lack of understanding how processes across departments affect each other. As the departments concentrates on their own agenda and plan, they do not take into consideration what the impact is on the project plan and other department plans.

RQ3: ***"What are prerequisites for performing sound activities in a procurement department?"***

Clearly defined guidelines on how procurement fit the current LPS structure has not been researched in the literature. By analyzing the current practice and applying rules and guidelines from other departments, we have during our research discovered a need to create a framework of prerequisites that must be fulfilled to perform sound activities. Increased focus on fulfilling these prerequisites can assist in integrating procurement departments in the overall structure to improve workflow.

Information and resources are the prerequisites we find to be required to perform sound activities in a procurement department. The information prerequisite is divided into four sources, i.e. information from the customer, information from suppliers, information from the engineering department, and finally, information from the production department. In terms of resources, this prerequisite is characterized by having a sufficient number of purchasers who have knowledge on negotiations and ability to manage communication with separate suppliers simultaneously.

Our empirical findings indicate that information is the most essential prerequisite for performing sound activities in a procurement department. Purchasers require information from both external and internal actors, and they are dependent on that information is available at the right time. Given that one of the main objectives for purchasers is to ensure that equipment is delivered to production according to plan and with correct functional specifications, their ability to perform the procurement process is challenging if the correct information is not provided. Further, we have found that information required for purchasers are from four different sources, i.e. from the customer, from suppliers, from DE, and from the production department.

Information from the customer is required for purchasers to understand which changes are desired from the customers as well as approval of suppliers throughout projects. For US, the SD communicates with the customer, and the information on requested changes is essential

for all departments due to the concurrent engineering approach. From a procurement point of view, it is essential to know which exact equipment to purchaser as soon as these changes occur to ensure that the equipment is available for assembly according to schedule.
Sending RFQs, receiving offers, negotiating contracts and commercial terms, and following-up on deliveries are activities that require information from suppliers. During projects the purchasers at US interact with a considerable number of different suppliers, and information sharing is essential to ensure that specifications are correct, shared quickly and that ordered equipment is delivered according to contracted terms.

Information from the engineering department are functional specifications of equipment in item requisitions that are converted into RFQs by the purchasers. These are sent to suppliers, and when they receive offers from suppliers, they once again need information from the engineering department to review the offers received from suppliers meet the customer requirements. The information from the engineering department is especially important because without a reliable information flow between these departments the purchasers cannot perform the procurement process to ensure that equipment is delivered, nor ensure that the equipment satisfies customer requirements.

From the production department, information on requested delivery dates and when equipment is scheduled for production is essential information which purchasers need to negotiate with suppliers. Based on our empirical findings at US, this information is generally not transmitted directly between the departments, but instead through the project plan. However, during projects there is usually a lot of direct communication between them if equipment is missing, or the incorrect quantity has been ordered, and we therefore propose that a direct dialogue between these departments is a prerequisite to avoid these challenges.

Lastly, resources are considered a prerequisite for sound activities in a procurement department because only qualified purchasers can perform the procurement process. Apart from the purchasers themselves, knowledge on how to negotiate beneficial agreements and ability to communicate with separate suppliers simultaneously is required. Therefore, resources in the form of purchasers with the required knowledge to perform the procurement process is considered a prerequisite for sound activities. In Figure 12, these prerequisites are presented.

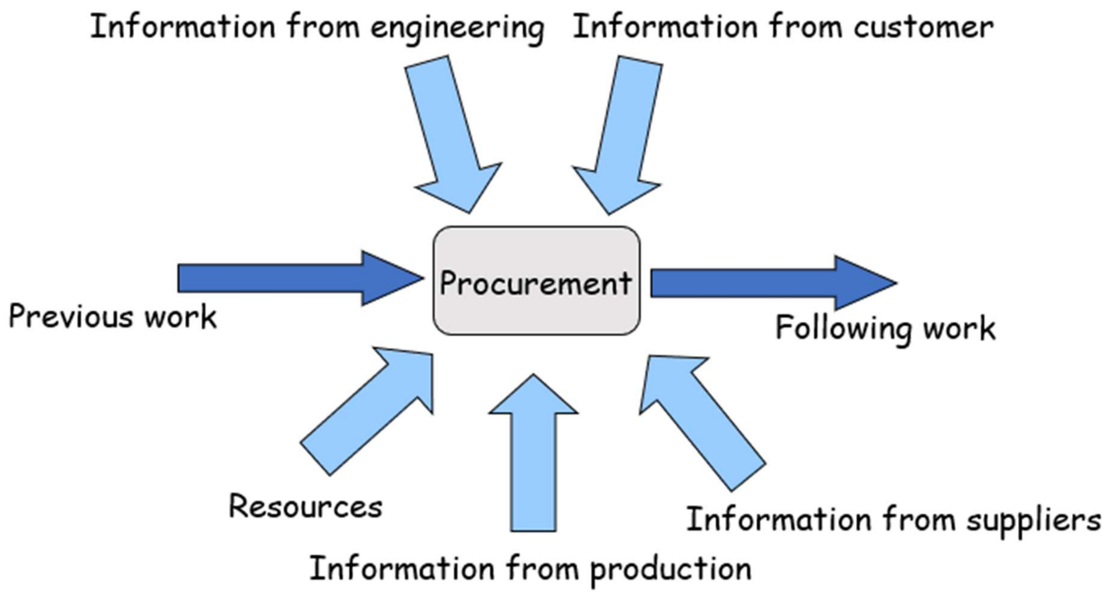

Figure 11: Prerequisites for Sound Procurement Activities

6.3 Previous Research

The main purpose of this research has been to conduct research on procurement planning in a complex environment, which we have not been able to identify in previous research. However, literature on procurement, industry characteristics, planning, and LPS is in this section compared to our empirical findings.

LPS was developed because the traditional CPM in project-based construction received critique as workers began to ignore the plans and instead resorted to ad-hoc solutions to make sure they stayed productive (Ballard and Tommelein 2016, Kalsaas 2017, Kalsaas and Sacks 2011). This is what is currently occurring at US, as their purchasers deviate from the developed project- and procurement plan and instead operate reactively based on their email inbox. This has over time resulted in waste in terms of waiting and backlog of tasks to be completed. However, we have no measurable empirical findings to claim precisely what the consequences are.

Ballard and Tommelein (2016) presented principles and rules for using LPS, and our empirical findings suggest that these are difficult to fulfill when offering customers flexibility with concurrent engineering and continuous changes. Moreover, not shielding downstream actors from upstream variations as described by (Ballard and Howell 1998), hampers the ability to plan procurement activities.

Part of the issue for US and their utilization of LPS may be explained by the barrier of lacking willingness to change (Sarhan and Fox 2013), but because LPS was implemented in US over a decade ago, it is more likely that US need to train their workers through courses on what LPS is and what benefits the system can provide if it is used properly. The barriers presented on lack of understanding lean principles is confirmed by our findings, while we agree that successful implementation requires commitment by management.

Further, our empirical findings indicate that implementing and utilizing LPS requires preparation and knowledge. Opposed to what Ballard et al. (2016) and Koskela (1999) stated on how LPS will stabilize projects through improved workflow, continuous information flow is a prerequisite for the system to work as intended. It seems like the system can assist in identifying where there is variability, however, our empirical findings cannot confirm that LPS can initiate actions for corrections and monitor if countermeasures are effective because such countermeasures have not yet been implemented by US.

The critique of LPS by Kalsaas (2013) and Emblemsvåg (2014) seems to be qualified in regard to further development for use in organizations who perform concurrent engineering, where this more specifically relates to what Kjersem and Emblemsvåg (2014) state, namely that adjustments are required to cope with the concurrent engineering approach. However, in their critique the procurement aspect is not included, and we therefore find it interesting to supplement the literature in this area. Even though US do not have LPS optimally implemented, there are several factors which emphasizes the need for adjustments, which include evaluation of how planning procurement activities must be included in the overall planning, not just challenges in design and production.

6.4 Managerial Implications

Managerial implications of this research are presented in this section. These implications are meant to assist organizations in understanding what challenges exist for procurement planning, and how the procurement department must be involved in business processes to perform tasks required to develop and maintain competitive advantages.

The main implication we have found is that the organizations must include all departments in the planning process because of the high level of dependency that exists between them.

We propose that managers must arrange for workers to study processes in other departments to understand how tasks are connected throughout the organization.

Organizations must include workers from all departments to perform activities such as PPC analysis, and root cause analyses such as PDCA and five whys. This must be performed during weekly project meetings to progressively measure completion of activities, improve decision making, and finally understand which countermeasures are needed to avoid problems from occurring. Moreover, LPS seems to be a system that cannot be partly implemented. This means that management in organizations must understand that a full implementation is required to use the system, and that failing to implement all routines may result in increasing complexity.

Our empirical findings suggest that to use LPS, all workers must understand how the system works to comprehend how processes impact everyone involved in the project. Managers in organizations who have implemented LPS or are considering implementation must ensure that workers understand what system they are working in. Moreover, increasing synergy between departments is required to achieve a reliable workflow and to utilize tools and techniques which can assist in handling the complexity in the construction industry.

Further, the role of procurement in construction projects has been emphasized in our empirical findings. The building process and current structure of projects in Norwegian shipbuilding companies seem to underestimate the importance of equipment procurement, and we encourage managers to increase the focus on how essential the procurement process is to manage lead time.

Lastly, we advise that organizations must ensure that prerequisites for sound activities are in place for the operative departments who are responsible for activities during the project. For procurement, our contribution is a model illustrating the importance of making information available continuously to avoid misunderstandings and delays caused by purchasers.

7.0 Conclusion

This aim of this research has been to contribute to LC and ETO literature by investigating how LPS can improve planning of procurement activities for a company operating with concurrent engineering. The RP we aimed to answer was:

RP: ***"How can LPS improve planning of procurement activities in companies using concurrent engineering?"***

To answer this RP, a single case study has been performed on the Norwegian shipbuilding company US, and three RQs have been developed and answered. We have investigated how concurrent engineering affects the ability to plan procurement activities in an organization who has previously implemented LPS, how the current planning structure of our case organization compare to LPS, and we have investigated which prerequisites must be fulfilled to perform sound activities for a procurement department.

To answer RQ1, concurrent engineering significantly increases dependency between departments for US. Because of this dependency, there is uncertainty internally between departments in US which makes it challenging to both plan and perform procurement activities according to plan. Allowing customers to request changes in design far into the engineering stages requires employees with specific knowledge, and as a result of this, the departments at US have become isolated. Thus, concurrent engineering hampers information flow between departments and leads to uncertainty in planning procurement activities.

To answer RQ2, both similarities and differences have been identified when comparing the planning structure of US and the LPS structure presented in literature. The similarities are mainly in terms of structure, where US operate with plans similar to the master schedule and the lookahead plan from the LPS structure, and project meetings are arranged. Conversely, there are several differences between the current practice and the principles in the LPS structure. US do not perform root cause analysis to identify constraints, and weekly project meetings are not used to make short-term plans. The information flow between departments required to perform these tasks is currently unreliable, which means that even though they have a planning in the organization that corresponds partly with the LPS structure, they are unable to utilize them.

To answer RQ3, we investigated if existing prerequisites for sound activities in production are applicable to procurement activities and found that two of the seven prerequisites are applicable if they are modified. As a result, we have developed prerequisites for sound procurement activities. These prerequisites are presented as part of the LPS structure to indicate what is required to plan procurement activities and show that the ability to plan relies on reliable information sharing from both internal and external stakeholders. The two prerequisites are information and resources, where we have presented four different sources of information and emphasized that resources are qualified purchasers able to negotiate with suppliers and communicate with separate actors simultaneously.

Based on these answers, our research has found that LPS can improve planning of procurement activities for companies using concurrent engineering. However, it requires implementing routines that aim to fulfill the prerequisites for sound procurement activities which have been presented in this research. With these prerequisites fulfilled, LPS will increase reliability of the information shared between departments, which accordingly will increase reliability of the planning structure and prevent workers from resorting to ad-hoc solutions. Furthermore, using LPS will lead to improved teamwork between departments as decisions are based on reliable information, and this makes it possible to perform root cause analysis and create short-term plans to handle the high level of complexity from performing tasks concurrently. Finally, LPS will improve the ability manage the dependency between departments by having qualified resources to manage processes and communication with stakeholders.

8.0 Limitations and Further Research

In this chapter, we present limitations of this research and encourage further research.

8.1 Limitations

The number of respondents in the interviews performed is a limitation to the concluding remarks of this study. Five respondents from the procurement department of US were interviewed for data collection. The aim was to understand their views and impressions on planning and execution of their work, along with what challenges they encounter. Because the respondents have separate areas of responsibility in their assigned projects, and additionally operate at different stages of projects, the generalizability of the information is reduced. To verify which challenges are the most significant requires information from more respondents working in the same circumstances.

Further, this is a single case study, which limits the external validity and generalizability of the research. A single case study was selected because of the limited time period of completing the research and the fact that we were approached by case the organization to conduct it.

Lastly, empirical findings of our research are solely based on interviews with supporting documents and records, and because no instrument has been used to measure the emphasized importance of information flow, the concluding arguments of this research may be limited. As we have collected information only from the procurement department, challenges revealed in the interviews may only represent views and perceptions of those experiencing the challenges, and not the ones that may be the source of the challenges.

8.2 Further Research

This research has presented prerequisites for sound procurement activities to be information and resources. These prerequisites have been developed based on a single case study, and we therefore encourage further research to investigate if similar challenges exist in other organizations using concurrent engineering. Moreover, we recommend further research to conduct multiple case studies of the shipyards in the local region of Møre & Romsdal to increase external validity and identify differences in planning and work structure.

In relation to the literary subjects of this thesis, we encourage future research to measure the effect of our developed prerequisites in both US and other organizations operating with concurrent engineering in complex environments.

A research topic that we have been made aware of by respondents during this research is the process of receiving goods from suppliers. The main challenge in the current practice is that both the warehouse and purchasers do not know how equipment is configured by suppliers. This complicates the process of collecting equipment for the production department.

Lastly, we have discovered that the shipbuilding industry is more complex than the ETO production strategy presented in the theoretical framework in this research. Design changes and potential CODPs that occur between the focal company and suppliers throughout projects are not represented. Further, the figure currently implies that customers determine design of the vessel in the engineering stage, but as our empirical findings in this research show, this is not the case for US. We therefore propose research to develop a figure that illustrates the continuous dialogue with the customer after the initial CODP, and how CODPs between the focal company and suppliers occur throughout projects.

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Appendices

Appendix 1 – Interview Guide 1

Introduction

- Can you describe how the plan used for procurement was developed in this project?
    - Who was involved in making the plan?
- What strategy was used to develop the plans?
    - Which factors are most important in the project (Price, quality, delivery times, service, guarantees)?
    - What were the main goals for procurement of the plans?
    - How and to whom are plans communicated?
- Do you measure how the project is performed based on the plan?
    - How do you evaluate the performance?
    - How important are time and cost for evaluation?

Processes

- How do you communicate with the others in procurement?
    - What problems occur during projects in the procurement division?
        - Are these known and repeating problems?
            - Were you aware that these problems could occur before the project was launched?
        - Which solutions have been applied to solve these problems?
        - What countermeasures are included in the plan for potential problems?

Suppliers

- Can you describe the process of supplier selection?
    - What criteria are used?
- Can you describe how often and why you do this?
    - Does this happen during projects, or between projects?
        - What is the threshold for switching suppliers mid-project?
- What framework agreements do you have with suppliers?
- What is your risk management strategy against unreliable suppliers?
- Can you describe the roles of the project purchasers and their work-relationship?
    - Do they work on a common objective with the same suppliers?

    - How is their individual and collective relationship with design/sales and detailed engineering structured?
- How are you involved in processes that are performed by the project workers?

Closing

- Do you have any suggestions on permanent improvements?

Appendix 2 – Interview Guide 1

Procurement

- Can you describe an ordinary day of work in a project for you?
- Can you describe what your role does in the initial stages of a new project?
- Do you follow a set plan for what you procure, or is information given to you during the project?
    - Do you have a milestone plan, monthly plan, or week plan you follow?
    - Are changes made to the plans after project launch?
    - Can you describe tasks that you have to do manually for every project?
- Do you perform processes where you are dependent on others in the procurement division?
    - How do you communicate with the others in procurement?
- Can you tell us about processes where you have problems performing your tasks?
    - In these processes:
        - How do you receive input and who do you receive it from?
        - What kind of input do you receive and how do you prepare it for performing your tasks?
        - Which output do you create and to whom do you send it?

Supplier selection

- How do you take part in supplier selection?
    - Which criteria are used for supplier selection?
- Can you describe the process of switching suppliers during a project?
- What is done by the procurement division to handle challenges with suppliers?
- Which factors do you consider the most important when procuring material (e.g. price, quality, delivery times, service, guarantees etc)?

Framework Agreements

- Can you describe the framework agreements you have and the process for selecting suppliers for these agreements?

Closing

Are there any specific areas or processes that you think should be analyzed in the procurement division to make information flow better?

Appendix 3 – Interview Guide 2

- How is procurement planned?
- How do you wish that planning of project should be performed?
- What is working properly with how the plans are made today?
- What is not working properly with how the plans are made today?
- Practical follow-up question on response from Interview 1:
- Which different locations are the vessels placed?
    - What is the difference between a hull yard and a regular yard?
    - Can you describe what you consider to be functioning best overall in projects, and why?
    - What are your routines to view and check the overall project plan that is made for the given project?

Appendix 4 – Interview Guide 2

- What is the content of a project plan?
    - What is the process of setting delivery dates?
- What is the content of a procurement plan?
    - What is the process of setting delivery dates?
- May we have a look at procurement plans you have made?
    - How do you use these?
- Can you describe step by step what happens from between the first sign of demand until the procurement process begins?
- Can you describe how you would like to plan purchases in a project?

In the previous interview, you revealed that reminders must often be sent to the technical department to receive item requisitions;

- Can you elaborate on the process of sending reminders to the technical department?
- How do you know when to send reminders to the technical department?
- Regarding receiving goods, how can you be better prepared for discrepancies when the goods received does not match the Purchase Order correctly?
- How much does the procurement department communicate with the production department opposed to with the technical department?
- Can you describe what you consider to be functioning best overall in projects, and why?
- What are your routines to view and check the overall project plan that is made for the given project?

Appendix 5 – Item Requisition

Requisition

Send requisition to Production Coordinator

<table>
<tr><td>Requisitioner:</td><td colspan="2">Purchaser:</td><td>Date:</td><td>Project No.:</td></tr>
<tr><td></td><td colspan="2"></td><td>10.04.18</td><td></td></tr>
<tr><td colspan="3">Recommended Suppliers:</td><td colspan="2">Remarks:</td></tr>
<tr><td colspan="3">PonPower / Caterpillar, Commins, Volvo Penta & Nogva / Scania</td><td colspan="2"></td></tr>
<tr><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td colspan="2">Technical Description (function/component/system):</td><td>SFI(min.3):</td><td colspan="2">Quantity pr. Ship</td></tr>
<tr><td colspan="2">Emergency generator set</td><td>665</td><td colspan="2">1 pc.</td></tr>
<tr><td colspan="2"></td><td></td><td colspan="2"></td></tr>
<tr><td colspan="2">Electrical Requirements:</td><td colspan="3">Remarks:</td></tr>
<tr><td colspan="2"></td><td colspan="3"></td></tr>
<tr><td colspan="5">Extract from Building Specification (all relevant related information):</td></tr>
</table>

66 OTHER AGGR. & GEN. FOR MAIN & EMERGENCY EL. POWER PRODUCTION

665 HARBOUR & EMERGENCY AGGREGATES W/EQUIPMENT

General

Diesel engine and generator are built on common base frame. Generator sets used as emergency source of power shall be air radiator cooled and have electrical start arrangement from batteries.

Pumps and still stand heater to be built-in engine. Generator to have anti condensation/still stand heating and be air cooled with fine grade filters. Generator to have winding temperature sensors and spherical roller bearings. Flexible coupling between engine and generator if not otherwise agreed.

Generator insulation class F and ingress protection rating IP23.

Type of fuel to be Marine gas oil according to ISO 8217, ISO-F-DMA.

Transfer of fuel from ship systems by transfer pump.

Ambient temperature for air coolers to be max. 45ºC.

Exhaust gas systems for motor aggregates, ref. Sub Group 744.

Emergency generator

Table 6.3 Emergency generator

Number of	Description	Capacity (approx):
1	Emergency generator set	350 ekW, 440V, 3 phase 60Hz

Size of the emergency generator shall be verified through electrical load balance calculations.

Separate fuel oil tank to be arranged, capacity according to mandatory Class requirements.

Emergency switchboard, ref. Sub Group 872.

Tech. Doc / Drawings from UVE:	Included(Y):	Remarks:
Arrangement or system drawings	NA	
General Arrangement (or part of GA)	NA	
Other..	NA	

Tech. Doc /Drawings to UVE:	Delivery Date:	Remarks:
3 D Solid model (JT, step, dxf or sat format)	09.07.2018	
Cable diagram (dwg format)	09.07.2018	
Calculations /analysis for …	09.07.2018	
Fresh water / Sea water cooling data	NA	Air cooled
Dimensional drawing w/ weight & center of gravity, flange locations and service space (dwg format)	09.07.2018	
Foundation footprint drawing (dwg format)	09.07.2018	
Load forces diagram	09.07.2018	
System specification and description	09.07.2018	
System/piping diagram (dwg format)	09.07.2018	
Wiring diagram (dwg format)	09.07.2018	
Heat emission from component to air	09.07.2018	
Spare part and tools list	09.07.2018	
Other..		
Optional Components / Systems and Other Services:	**Delivery date:**	**Remarks:**
Engineering / Installation manual, including electronic (2+1 pcs)	Week 40 2018	
FAT / test protocol	Avkl. senere.	
Instruction manual, including electronic (3+1 pcs)	Avkl. senere.	
Material Certificate, Type 3.2 (3.1.C)	Avkl. senere.	
Other..		
Delivery dates for equipment:	**Delivery date:**	**Destination/Remarks:**
Commissioning	Avkl. senere.	
Other..		