SPECIFICATION STANDARDIZATION OPPORTUNITIES IN MARINE LIFTING DEVICE PROJECTS IN ETO JIT SHIPBUILDING ENVIRONMENT

Lappeenranta–Lahti University of Technology LUT

Master's program in operations management, Master's thesis

2023

Teemu Vartiainen

Examiner: Professor, Janne Huiskonen

ABSTRACT

Lappeenranta–Lahti University of Technology LUT

LUT School of Engineering Science

Industrial Engineering and Management

Teemu Vartiainen

Specification standardization opportunities in marine lifting device projects in ETO JIT shipbuilding environment

Master's thesis

2023

83 pages, 7 tables, 4 figures, and 5 appendices

Examiner: Professor Janne Huiskonen

Keywords: Projects, Engineer-to-Order, Shipyards, Shipbuilding, Standardization

This thesis was conducted as a development project to define a standard specification for maritime lifting devices for service use. In the Marine unit, the project duration is generally long, and are highly exposed to price increases and fluctuations regarding materials and engineering. The research was focused on smaller projects and ships containing maxim on five lifting devices per project.

The projects are done as ETO projects, delivered with JIT principle. The thesis aims to get cost savings from reduced engineering by standardizing most parts of the specification. The standard specification leans heavily on CRM based pricing and specification creation and up keeping tool that is going to be used in newly starting projects in the future. Cost savings are compared with closed project cost analysis and modern state.

The conclusion of this thesis is that the specification cannot fully be standardized, since the shipping industry lacks some required standardizations. As every ship is designed individually, there are multiple aspects that can vary from ship to ship. Standardization would require a lot of compromises from the customer, which is not realistic to assume at the moment. With the features that can be standardized, light-ETO specification has been created with CRM based specification and pricing tool. Also, it is proposed that a global drawing library should be created. The library would be created to fulfil required documentation of the project. The documentation is required by the shipyards, the classification societies, and the customers. Furthermore, existing manufacturing drawings are recommended to utilized in projects as bases for future semifinished product production, in order to save costs.

TIIVISTELMÄ

Lappeenrannan–Lahden teknillinen yliopisto LUT

School of Engineering Science

Tuotantotalous

Teemu Vartiainen

Spesifikaation standardisointimahdollisuudet Marine-nostolaiteprojekteilla ETO JIT laivanrakennusympäristössä

Tuotantotalouden koulutusohjelma, diplomityö

2023

83 sivua, 4 kuvaa, 7 taulukkoa ja 5 liitettä

Tarkastaja: Professori Janne Huiskonen

Avainsanat: Projektit, Engineer-to-Order, Laivan rakennus, Telakka, Standardistointi

Tämä diplomityö tehtiin kohdeyritykseen kehitysprojektina, jossa määriteltiin standardisoitu tekninen määrittely laivateollisuuden nostolaitteille huoltohenkilöstön käyttöön. Marine-projektit ovat pitkäkestoisia, jolloin nämä ovat alttiita materiaalien hintatason vaihtelulle ja kustannusten nousulle. Tässä työssä keskitytään pieniin Marine-projekteihin, sisältäen enintään 5 nostolaitetta.

Marine-yksikössä toteutettavat projektit ovat vahvasti JIT-, ETO-projekteja. Tällä työllä pyritään osoittamaan keinoja vähentää suunnittelun määrää ja hakea sitä kautta kustannussäästöjä materiaalien kilpailutuksen lisäksi. Spesifikaatio nojaa paljolti CRM-pohjaiseen tarjoustyökaluun jossa ylläpidetään spesifikaatiota ja hinnoittelua kaikilla uusilla projekteilla. Kustannussäästöjä verrataan suljettujen projektien toteutumasta tehtyyn analyysiin ja nykytilaan.

Tuloksena tutkimuksesta selviää, ettei nostolaitteiden spesifikaatiota saada täysin standardisoitua, johtuen laivanrakennuksen standardisoinnin puutteesta. Näitä ei ole realistista olettaa laivarakennustelakoilta kirjoittamisen ajankohtana. Jokainen yksittäinen laiva suunnitellaan teknisesti uudelleen. Tästä johtuen kevyt ETO-spesifikaatio on luotu CRM-työkaluun nojaten. Tähän tueksi työssä ehdotetaan että luodaan globaali piirustuskirjasto käytettävistä laitteista, jotta telakan, luokituslaitoksen ja asiakkaan dokumentaation pohjat olisivat valmiina asianmukaisessa muodossa. Myös teknisten valmistuspiirustusten käyttöä ja samojen laitteiden kopiointia suositellaan suunnittelun ja kustannusten vähentämiseksi.

ACKNOWLEDGEMENTS

I am grateful for the opportunity to conduct my masters' thesis while working in the case companies' Marine unit. Thank you, Monna and Mikko for supervising the thesis, understanding the schedule postponements, and inspecting the final product on a short notice before releasing it. Also, thank you Monna for adjusting my workload so, that the working on this thesis was possible.

I want to also express my gratitude to my fiancé, Laura for supporting me during this process. Thank you for understanding and support at home and being present when it was most needed. Without it, the thesis would have never been finished.

ABBREVIATIONS

ETO	Engineer-To-Order
MTO	Make-To-Order
OPP	Order Penetration Point
CRM	Customer Relation Management
SLD	Service Lifting Device
PLD	Passenger Lifting Device
SL	Supply line
FL	Front line
PM	Project Manager
SM	Supply Manager
CDE	Chief Design Engineer
GA	General Arrangement
NRP	No-Return-Point
COP	Cabin Operating Panel
ERP	Enterprise Resource Planning
BOM	Bill of Materials

Table of contents

Appendices

1 Introduction

In this section, the business case is introduced, methods and research questions are briefly reviewed. Also, the section sheds light to some challenges that have been noted from the standardized equipment development process and why this development has been discussed for more than two decades.

1.1 Business case in brief

The case company where this thesis was conducted produces lifting devices and people movement and access solutions. In the case company, the thesis target division specializes in maritime solutions for different types of ships, vessels, maritime applications. There are two major categories of lifting devices, and their features differ mostly on the decorative side within the lifting device cabins and exterior visible to the user. The usage is for passengers and for crew. The passenger model is more decorative and aesthetically pleasing. The crew model is more often quite plain and has the necessary equipment as in the operating panel and standard required safety features attached. The crew models have been designed with functionality first in mind.

The crew lifting solutions are quite similar to each other across different projects and customers. The major differences between different crew lifting devices appear in the shaft dimensions: width, depth, and travel length. The travel is defended by the operated decks on the ship. Despite the similarities between the crew lifting devices, these devices are custom engineered to fit each and every ship project perfectly. In order to accomplish this, a significant amount of engineering is conducted, and their effort is needed, which brings the overall project costs up. There is a quite significant cost saving potential seen in standardizing all lifting devices, in contrast to the need for each and every custom engineered lifting device solution. All the engineering would be obsolete in this vision.

In the Marine unit this cost saving potential has been seen some time ago. There have been multiple attempts to create a standard solution on the lifting devices. Since this has been noted, there have been multiple development projects started and are in progress improving

the process in general. One of these is an ongoing new tool implementation for specification up keeping and product pricing tool linked to the company-wide Enterprise Resource Planning (ERP) system. This system makes the standard process more possible in principle. With this updated system, products can be more harmonized and for example product specific features listing work can be reduced.

The new Customer Relationship Management (CRM) software-based tool for specification and pricing allows the specification selection to have a very wide range of options, which can result in a product that needs to have custom engineering. This means that with the new system, there is no guarantee of making a standard product for the customer. This results in the need of this thesis, where the goal is to limit the options so that the product can be called a standard product.

As lifting devices are quite complex products that can have special features such as a linking capability between each other and variable custom features, everything cannot be standardized. Usually, the bigger the project, the more there are customized features with materials included in projects and with installation methods. These features can be anywhere from doors made from glass to pre-outfitting electrical and mechanical components to supporting steel structures on subcontractors' premises. This requires a lot of engineering and planning, and hence the process has not been standardized yet. With these variables considered, the thesis scope was limited to focus only on smaller projects containing only 1-5 lifting devices in total, where the hypothesis was that the standardization is more likely possible.

1.2 Thesis methods and research questions

The re-search methods in this thesis are qualitative. In the first part of the thesis, theory has been qualitatively gathered from specific topics that have been chosen during pre-writing phase of the thesis. The theory is presented briefly to illustrate the specialities in the topics, so that for instance the Marine environment is covered briefly. Additionally, company internal data has been analysed and presented in brief. The data used to find out the status of the Marine unit projects has been qualitatively filtered, so that the results would give the most accurate picture possible of the current cost structure and engineering spent hour.

Meetings with different Marine organization personnel play a key role in defining the standard lifting device specification. The specification defining and corporate material pricing is heavily leaning on a CRM based tool used in the case company. Although the CRM tool specification is still in late implementation and piloting phase, it is used here since it will be used for all upcoming future projects.

The target of this thesis is making a project specification, that can later be used to deliver successful lifting device projects, with successful supply processes and installations. It is very important to have the specification working with newly implemented tools and to be in line with other various development projects, to avoid extra consolidation work.

With these limitations and points of interest, the research questions have been formulated as follows:

- Can small Marine projects be transferred from ETO to MTO projects and offer a Marine standard solution to customers, with clear limitations and successful execution?
- What is the cost for the standard MTO lifting device, and can the sales price be reduced to make the case company for more attractive option to the customer with small projects?

The main focus with the research is heavily leaning towards the engineering, purchasing, and delivery processes.

Although sales and installation processes are a key parts in successful Marine projects, these mentioned but not addressed with so full detail. With sales, this is due to the influence being quite small to the engineering process. With site installations, there are little differences in the methods for installations depending on the shipyard or subcontractor the is observed. Also, the installation process has been developed heavily from conventional scaffolding installation to more specially applied installation methods. These consider better the ship construction processes in place and take advantage of the already installed materials.

2 Theory for the thesis

In this section, the theory that is used in the thesis is introduced. Most of the theory is related to projects in general and engineer-to-order projects in a heavy manufacturing industry. As this thesis was conducted in the case company's Marine unit, ship building industry and outfitting processes are introduced on a general level. Also, LEAN production and management play a key role in the company's strategy, efficient just-in-time deliveries and their key building blocks are shortly observed.

2.1 Projects and project management

Projects have multiple definitions with different organizations and authors. Although the definitions differ from each other, there are multiple common characteristics. The common characteristics are that projects involve change, have limited time constrains, are complex and have an evolving vision or concept, are hard to plan and guide, require resources, involve different types of risks and require their own organization. (Kuster et al. 2015, 5-8)

The field that the project is concerning can be categorized within seven different classes based on their purpose. The seven categories are investment projects, infrastructure projects, product development projects, organizational projects, organizational development projects, information technology projects and construction projects. (Kuster et al. 2015, 5-8)

Another perspective for project categorization is presented by Lock's book (2012, 6-9) and is to divided project into four general types: civil or chemical engineering and construction projects, manufacturing projects, management projects and projects for pure scientific research. The categorization is not universal but for example shipbuilding and construction can be filed under manufacturing projects in Lock's categories but would fall under construction projects with project management handbook definition (Kuster et al. 2015).

In George Bruce's book, Shipbuilding management (2021. 33-35) projects are defined as:

> "A set of linked activities conducted in an organized way, with a defined start and finish date."

The concluded activities in the process are not standardized, although some mundane tasks are involved. In shipbuilding, tasks usually occur once in a ship's construction process which is one of the main reasons why these are considered as construction projects. There can be multiple similar projects, such as a series of ships, but these are considered as individual projects. The building process has finite lifespan and follows project lifecycles in four phases which define actions for work: definition, planning, executions, and closure. A shipbuilding project often has development of new products or features. (Bruce, 2021, 33-35)

2.1.1 Manufacturing projects and their success factors

As previously presented, there are many types of projects, and the project deliverables may change drastically depending on the scope and environment. One of these types are manufacturing projects that Hayes and Wheelwright (1979) describe in an article as being projects that manufacture large individual goods. These include such goods as production lines, cruise ships, aircraft, and space shuttles. All of these are large entities that have required special engineering before manufacturing the large and complex products. (Hayes & Wheelwright, 1979)

In the manufacturing projects, the key success factors which lead to a successful product delivery are not that self-explanatory as there are a lot of different aspects to consider. As these are not that self-explanatory, there have been multiple studies conducted on the topic. One of these studies is a study conducted by Pacagnella, and others (2019) to conclude in sourced data from 182 respondents from different industries to identify these key factors. The study concluded that not all success factors that literature supports are reflected in the data collected as statistically significant factors. The factors have been separated into to four different groups: Efficiency, impact on the customer, impact on the team and preparation for the future. Under each of these groups, 5-7 different statistically significant factors were noted. These are presented in Appendix 1. The statistically significant factors have an additional subgrouping in following categories: human resources (HR), technical aspects

(TA), project management (PM), organizational factors (OF), and relationships with stakeholders (RS). From counting the number of items in the second categorization, project management related factors account for nearly half of the success factors. (Pacagnella et al. 2019)

The success factors that are under project management include items reflecting scope, risks, and limitations from the environment, schedule, and budget management. Almost the same elements have been recognized and presented in other sources, such as in the book Project Management by D. Lock (2012) and Project Management Handbook by Kuster and others (2015). These factors are often raised to a higher level and presented in triangle as three major points that need to be balanced with each other in a well performing project. These three tips of the triangle are costs, schedule, and quality. In this presentation way, the scope is considered as a part of quality, since without fulfilling the scope agreed with the customer, the project cannot provide dissent quality. Kuster and others (2012) call this presentation model playfully as the magic triangle.

All the aspects mentioned above need to be balanced in order to deliver a successful project. The triangle has multiple versions depending on the author. In a book "Project management" by D. Lock (2012) there are four versions presented, including one by the author. D. Lock's own version attempts to combine these as replacing level of quality to level of specification and adding people to the centre to indicate that all the other factors affect the stakeholders and people.

2.2 Shipbuilding projects

Shipbuilding industry is considered as business dealing with building mainly seagoing ships or vessels transporting mainly cargo or passengers, used for offshore energy industry, or used with military and defence purposes. In addition to building ships, the industry includes other products and services that are supplied for ship building, ship conversing and ship maintenance. These operations can roughly be divided into different fields; service and modernization business area and new build business area (Ramirez-Peta et al., 2019). Operations in the modernization and new build business areas are mostly conducted on shipyard or very close to the shipyard facilities and the materials come from various sources

into the dock. Hence, these can be considered as a type of complex manufacturing process (Ramirez-Peta et al., 2019). The European commission has recognized about 150 large shipyards in Europe, that include 40 shipyards that have the capacity to build large commercial vessels such as cargo ships and cruise ships. (European commission, 2022).

New-built ships are most often one-off constructions and are usually described as complex manufacturing projects. The project execution methods vary from one shipyard to another, but the end project deliverable is a ship that most often fills the customer requirements and expectations. The ships go through the several different project execution phases. The project executions phases start from engineering and continue from structure assembly and outfitting to commissioning and sea trials to customer handover. (Wei, 2012)

Regarding newly built ships, blocks are discussed in the contacts. A ship block describes a steel unit that is assembled and lifted on the hull. These are welded together, and to give shape to the ship hull. It is important to have the correct blocks in the correct place for the outfitting at the correct time to increase efficiency of the shipbuilding process. In a New Your Times 2020 article, there are very descriptive pictures and illustrations of the blocks and their lifting onboard, which are presented in Appendix 5. (Chokshi & Paynem, 2020) (Bruce, 2021, 91-92)

In ship modernization business there is less flexibility on the scope and measures since there are more limitations with existing structures that are already on board of the existing ship. Still, modernization projects can even change leght of the ship by adding a piece to the hull if required, as France shipyard Chantier De L'Atlantique (CdA) markets on their website (2022).

After the ships have been built and head off to operate with their target sailing area. The sailing area is defined by demand, and customer demand on the market is very heavily focused geographically. In a 2015 study it was pointed out that the total global market has been growing steadily between 1990 and 2013 on average 7,84 per-cent annually and will keep on growing. In 2012 the market share including cruise shipping and river cruising was divided to 56 per-cent in North America, 30 per-cent in all of European Union and 14 per-cent in the rest of the world. According to some estimates the market size reached 27,48 billion USD in 2019 just before the Covid-19 pandemic, concentrating in the US market with 13,30 billion USD (Statista, 2023). This is about 48,4 percentage of the global market in

2019 and there are estimates placed that the market will grow to 35,87 billion USD by 2027 (Statista, 2023). As the cruise market is concentrated in on North America and the Europe, the ships must be built so that they take into consideration the area quality requirements. (Esteve-Perez & Garcia-Sanchez, 2015)

2.2.1 Outfitting

Outfitting is described by the United States department of labor; Occupational Safety and Health Administration (2022) as the process where, in a ships' context: installing a ships' propulsion system and various support systems. The support systems include for instance HVAC (heating, ventilation, and air conditioning) systems. Outfitting also covers installations of insulating materials and all other fixed materials needed on the ship. Inside shipyards, there can also be dedicated areas to do certain section outfitting. This is called zone-outfitting. A zone can cover for instance the ship's machinery department or the cargo hold. This makes the incoming material management easier since certain sections have a dedicated area where they are installed to the hull. This can result in cost savings by reducing assembly time in a bigger shipyard. (US department of Labor, 2022; Marine Insight, 2019)

Many shipyards subcontract outfitting work as the work is low value adding work on the project and with this shipyard employees can focus on more value adding tasks such as material lifting on board (Bruce, 2021, 46-47). Low value adding work can be considered as cleaning, scaffolding, and painting for instance. As all outfitting is not mandatory to do at the shipyard, the block manufacturer can do a significant part of the outfitting at their premises for an additional cost. The scale of subcontracted outfitting needs to be re-observed for all cases individually. (Bruce, 2021, 46-47)

Outsourcing the outfitting can also make the shipbuilding process more efficient and effective. Furthermore, outsourcing the blocks building to various smaller shipyards, more work can be done simultaneously. Regional differences do occur and according to Schank et al. (2005) and it is especially common in US shipyards. In addition to outsourcing the block building, outsourcing the outfitting can reduce construction time on the primary shipyard since most of the outfitting is already done. (Schank et al. 2005)

In the study conducted by Schank et al. (2005) it was found that outsourcing practices include two types of outsourcing. These categories were called total outsourcing and peak outsourcing. Total outsourcing was described as similarly to the block building and outfitting in an external shipyard, as the main work is done outside the primary shipyard where the ship is being built and put together. Peak outsourcing has been described as work that is done on the primary shipyard by an external company to temporarily increase the in-house capabilities. The necessary special skills can be gained to the shipyard for the time that they are needed. This can be targeted to installing special equipment such as propulsion system. (Schank et al. 2005)

Schank et al. also state that not all the work can be outsourced from ships. For instance, if the capabilities are possessed in-house there is no reason to outsource it, unless there is risk of high penalties due to delays. Also, especially with military ship's, weapon systems raise safety concerns and hence their installation is kept in-house in the UK and in the US. (Schank et al. 2005)

2.2.2 Just-in-time deliveries with shipbuilding

The shipbuilding and construction industry has been described as having three significant characteristics: high modularization, having a vast number of pieces and parts, and that the pieces span over a variety of different fields. This makes the shipbuilding projects highly complex, with causal relationships, where errors can multiply their magnitude easily. The industry has also been criticized to have serious environmental issues. Due to these issues, it has been recognized that using LEAN methodology, can reduce waste. Unnecessary production phases can be avoided, and material and human resources can be reallocated to more efficient tasks. (Wang et al. 2021)

One of the key LEAN ways to manage the fragile supply chain in shipbuilding is high quality supply management. This is an essential part of the process due to the highly complicated supply chains and high number of complex parts that are linked to each other. Just-in-time deliveries have been proven to bring benefits in the fields of quality, time-based responses, increased profitability, reduced inventory, accounting simplifications and employee flexibility with the requirement that JIT production is managed properly (Fullerton &

McWatters, 2001). Applying the JIT method in inbound logistics at shipyard can bring competitive advantages if implemented optimally. (Wang et al., 2001). JIT has the ability for flexibility which in shipbuilding context is required. This is due to the high likelihood of changes in planning, especially with cruise ships, hence it is important to plan the logistics as well as the procurement plan, pallet centralization plan and production plan. (Zheng, Ke & Wang 2021). Operating on JIT system the production schedule delay, and inventory backlog risk rises but gives subcontracting companies the flexibility that is required with changing delivery plans and block plans. (Wang et al., 2021)

2.3 Process standardization

The complete definition of standards and standardization is a debated topic in scientific literature, as Münstermann & Weitzel (2008) point out in their article. The article found the as one authors required four elements in the standardization definition, there are quite many examples where this is missing. These four elements are the entities that standardization is related to, the industry and context where standards can be applied, the initial purpose for the standards and the ways of parties' involvement. As not all contexts fulfil all these elements, IEC/ISO has stated the definition for standard is:

> "Document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context" (ISO/IEC, 2016).

ISO/IEC also recognized that the standards should be based on consolidated research results, experience, and technology. This is to optimise the common benefits of the standards. (Münstermann & Weitzel, 2008)

Process standardization has been proven in an empiric study to have a positive impact on process efficiency on all three project management key measures: schedule, costs, and quality. The studies note that although the results are promising, there are requirements such

as the correct implementation of LEAN management tools, and individual industry requirements that need to be considered. The studies also suggest that with standardization value adding work can be prices and accurate which leads to performance enhancement with better resource management. (Münstermann et al. 2010 & El-Khalil et al., 2019)

Standards can be utilized in different ways. One of the ways is to provide guidelines to quality functions and be used as one tool in Total Quality Management. To support this, there is even a specific quality management standard set for quality management – ISO 9000 family of standards. This includes guidelines to quality management systems. The ISO 9000 standards can be used for different applications such as internal audits, vendor assessments and proving supplier capabilities. (Naidu, Babu & Rajendra., 2006, 63-89)

2.3.1 Classifications and certifications on shipbuilding projects.

Quality and safety are visible in day-to-day work in Marine industry environment since many types of certificates and other documents are required by the shipyards and shipowners. These certificate requirements originate from various sources.

Passenger and cargo safety are a priority in maritime business, along with environmental factors. This has been recognized by many parties, such as the United Nations. Hence, under the United Nations, the International Maritime Organization (IMO) was established in 1948. (IMO 1, 2022). IMO concluded many types of organizations that guard the specification requirements for treaties or resolutions that define the standards. As the standards and treaties are valid across nations, IMO is a good forum to agree on the details included in these. Conventions are held to check and update the regulations and requirements. The most notable of these so far was the international convention for the Safety Of Life At Sea 1974 (SOLAS), concerning the safety of merchant ships. The SOLAS convention was initiated from the sinking of the Titanic, to prevent such disasters in future. (IMO 2. 2022, IMO 3)

Different certificates can be applied from classification societies (Classes) such as Lloyd's Register, RINA or DNV. All mentioned are members of the International Association of Classification Societies (IACS 1, 2022). IACS goal is to provide ships of all types certificates that ensure the safety and environmental friendliness of the ships (IACS 2, 2022). Classes see that all the ships that they approve have the correct documentation after testing, and they

are in line with Marine Equipment Directive (MED), which is issued by the EU commission. (LR, 2022.) Alongside of MED, there are similar directives defined from the UK; United Kingdom Conformity Assessment (UKCA). (LR. 2022) With these classifications and component certifications, it is encrusted that the ships built have been constructed with good and tested materials and that the safety and reliability can be trusted (IRCLASS, 2022). In addition to the safety, environmental aspects are rated by the class. The Classes see that all needed documents are validated and handed over to the ship after the requirements have been filled. Ships will cruise with these documents to prove their completeness to the placed restrictions. Classes make can ensure that certain parts of the ship are compliant with the necessary standard such as ISO 8383 with elevators or ICS 47.020.20 for Marine engines and propulsion systems (ISO 47.020.20, 2022 & ISO 8383, 1985).

The classifications have a straight and concrete link to safety on a ship. An example of safety regulations is with Finnish ports in wintertime. According to the Finnish Transport and Communications Agency (Traficom), Finnish and Swedish authorities have developed the Finnish-Swedish ice class, which classifies ships to six different classes by hull durability and motor capability. With these classes, winter conditions make it mandatory to have icebreaker assistance in the Northern Baltic Sea. Still in the end, the shipowners are responsible of the ships' and have the responsibility to comply with the ice class ruling. (Traficom, 2022)

The classification can also have a financial impact on the ship's operations. In Rotterdam port for example certain certifications can help to reduce tariffs and so, impact heavily on operating costs. With lower emissions from the propulsion system certificates discount rate can even be 100 percentage from the basic tariff set on the ship. These examples highlight the importance of the certificates for the ship's owners. (Port of Rotterdam, 2022)

There are numerous other examples for these certification requirements that need to be considered in Shipbuilding. These requirements need to be known in very early phases of the ship building so the engineering and material sourcing operations can account for them. As the ship's owner or shipyards apply the certificates individually per ship, correct building methods and correctly certified materials must be used to pass the class testing and certifying process. (DNV. 2022) The materials can require underwater tests or material strength and corrosion tests. Subcontracting material suppliers need to take these into account and provide the required certifications as their products are handed over to shipyards and to customers.

This might also affect the sub-supplier selection, since classes offer supplier certifications verifying the production quality (DNV, 2022).

2.4 Order penetration point and manufacturing strategies

As many companies across different industries shipping goods have expanded their client base to answer the global demand, the popularity of optimised production and process re-engineering has gained popularity. This can be seen with the rising popularity of process improving systems such as LEAN among different managers as noted in an article by Bamber, Stanton, and others (2014). As there has also been concrete evidence that re-engineering can provide greater efficiency for processes, the management interest is self-evident. The pioneering example from improving processes and re-engineering production is with Toyota Motor company, where the LEAN methodology was first developed and recognized. Since the proven results, the Toyota way has been the target of research in order to understand and reproduce the results in different context. The ideological change has meant that manufacturing ways have been modified so that waste is very minimal in the production process. There are multiple studies and books analysing the methods and innovations on process engineering to see the actual results. (Bamber et al., 2014. & Gao and Low, 2014)

The re-engineering can be done by changing the customer involvement in the process. This can affect for example on the customer having more control on the final product features and lead time. This shows the company as placing the Ordered Penetration Point (OPP) in a certain point of the process. OPP is a term that is used to define the point in the manufacturing process or value chain link with particular product is linked to a customer order. The OPP defines the product delivery strategy or manufacturing strategy that can be used in fulfilling the customer demand by placing the customer involvement point in the value chain. (Olhager, 2003)

In literature, OPP is also referred as being customer order decoupling point (CODP) or decoupling point (Mishra, 2019.). For the sake of simplicity, this thesis uses OPP instead of multiple terms for the same concept. A company needs to decide the OPP placement so that it creates as much value to the customer as possible. Variables that affect this decision are

the production volatility and volume, as well as the customer's lead time requirements. Also, the level of customization may limit the possible options to the customer.

According to an article written by Jan Olhanger (2003) that was published in the international journal of production economics, there are four major points for OPP placement in the value chain. These are engineer-to-order (ETO), make-to-order (MTO), assemble-to-order (ATO) and make-to-stock (MTS). The same manufacturing strategies have also been identified on other article authors as well. (Atan, et al. 2017). In table 1 these strategies are presented with the OPP linked to the different value chain phases. These phases are designing, fabrication and procurement, final assembly, and shipment. (Olhager, 2003).

In another article by Golsing and Naim (2009) literature review was conducted, and they identified six different possible range of operations or manufacturing strategies. These were engineer-to-order (ETO), buy-to-order (BTO), make-to-order (MTO), assemble-to-order (ATO), make-to-stock (MTS) and ship-to-stock (STS). In the literature review, Gosling and Naim focused on ETO and how this reflects supply chain management. (Gosling & Naim, 2009)

Table 1. Product delivery strategies reflect different order penetration placement in the value chain. The value chain is modelled with four steps from design and engineering to final shipping of the goods to customer. (Olhager, 2003)

Value chain phase / Manufacturing strategy	Design	Fabrications and Procurement	Final assembly	Shipment
ETO	OPP			
MTO		OPP		
ATO			OPP	
MTS				OPP

The key differences here with ship-to-stock and make-to-stock is the material supplier; one has an internal production facility and other external. There is a similar difference between

make-to-order and buy-to-order, that the material supplier is either internal (MTO) or external (BTO). In varying literature there has also been other strategic approaches recognized with only minor differences to the already mention manufacturing strategies, such as Configure-to-order (CTO) (Ciccoi et al. 2019). As these differences are minor and can be mostly dealt with on a higher level, most of these are now presented in detail in this thesis.

Some companies are in the position of being material suppliers by themselves which purchases parts for its own production and in addition can have complicated supply chains for different components. BTO strategy is not seen as beneficial to address in detail in the context of bigger global companies. With these types of companies, often the goal is to have Lean operations as the base of business. The right resources are required to be at the right location at the correct time. This is also the case with the case company. Also, as the goal is to minimize additional warehousing cost and non-efficient stocks, it is not too beneficial to pay attention to ATO, MTS and STS strategies in depth here.

2.4.1 Engineer-to-Order and Configurate-to-Order

Engineer to Order manufacturing strategy can be defined with OPP placement in the value chain. If the customer involvement is in the design phase and the order placement is still within the design phase, the manufacturing strategy is ETO (Olhager, 2003). As the order is placed before any material is stored in warehouses and the material cannot be manufactured in advance, ETO is identified as a pull system similarly to MTO systems (Rafiei & Rabbini, 2011). This is because Rafiei and Rabbini (2011) have identified the transition point between push and pull systems in processing, between procurement and delivery.

The order placement initiates the design process and manufacturing. As is shown in Table 1, OPP is within a very early stage of the value chain. This results in customers having a possibility for high effect on the product characteristics. On the other hand, the lead time is very long for ETO products. The lead time is long for the product handover due to the fact that basically little to no actions can be done in advance to prepare for the production before OPP has taken place. This results in all the manufacturing process starting only on OPP and reflecting the overall lead time. (Olhager, 2003)

ETO products often require additional time in the quotation preparation phase. This is to ensure the scope of what is included in the quotation. This is due to the fact that in ETO products, customer requirements cannot be fulfilled by already existing preconfigured solutions. In addition, ETO typically requires engineering development before the production can be executed. This can be accomplished by modifying internal processes and tools or subcontracting the necessary material or know-how. Configure-to-order (CTO) is often associated with ETO but differs so that already existing configuration is only modified so, that it fulfils customer needs. This does not require additional development in the engineering and manufacturing processes. (Ciccoi et al. 2019)

As the difference between CTO and ETO is quite small, and the manufacturing process changes can be easily outsourced to an external supplier. ETO is used as the term defining customer specific and tailored solutions that have OPP in a very early phase of the value chain. ETO is often present with high monetary value goods that are complex entities such as ships, airplanes, and special purpose machines (Kolisch & Brachmannm, 2021). As there is a significant amount of subcontracting used with these fields as mentioned earlier, a great deal of facilitating is required while building these complex entities. That is one major reason why there are engineering approval processes in place. In the maritime environment, if the approvals are not received the classification society will not accept the ship and so ships cannot be finalized. This also results in customers not accepting ships. Hence, approvals are needed for the design and execution. (Roth & Lee, 2018)

In some literature, ETO products that are done as projects are also referred to as manufacturing projects. In these projects, the quantity of produced products is small and have been specially designed for the project. In addition, as the technical complexity rises in the projects, the operative and financial risks are also greater. Furthermore, it has been recognized and stated that the engineering in ETO manufacturing take a significant amount of the lead time; some studies estimate that the proportion is about 50 percent of the total lead time. (Willner et al. 2016; Yang, 2011)

2.4.2 Make-to-order

As presented in the earlier chapter, the OPP defines the manufacturing strategy. Moving the OPP from engineering and design to fabrication and procurement changes the strategy as make-to-order strategy. MTO has been identified as a pull system since the order initiates the production system actions for the specific goods. (Rafiei & Rabbini, 2011). Key features of MTO strategy are that there is no inventory of products, but the design for the product is ready and available for the customer. There can be semifinished products, but the products need maintain the flexibility to be manufactured only according to the customer requirements (Rajagopalan, 2002). Like ETO products, MTO products require a customer order placement in order to start any action and before the manufacturing process will be initiated. As there are no semifinished products in stock, the products have risks of delay due to lacking raw materials, which may cause delays. (Rafiei, Rabbani and Kokabi, 2014)

Considering that there is no engineering involved in the manufacturing phase and, the offering is much more limited to the customer. Furthermore, the lead time might be one of the key performance indicators which require careful monitoring with product that have no engineering included, as is described by Öner-Közen and Minner (2017). Often the MTO strategy is mixed up with MTS in order to satisfy the customer demand in the appropriate lead time. The balance of products that are manufactured within MTS and MTO strategies is something that needs to be investigated individually for each environment using analysis of the whole supply chain demands and capabilities. (Rafiei, Rabbani and Kokabi, 2014; Öner-Közen & Minner,2017)

2.4.3 Shifting OPP in the value chain

OPP positioning is a strategic decision to a company, as the chosen strategy has its benefits and trade-offs. The decision needs to be estimated and justified based on the industry the company is operating in, market demand, product and production limitations. In scientific research, there are methods for defining the optimal manufacturing strategy and OPP placement. An example of this is Tiemoury & Fathi's (2013) article, where a model was

developed so that it would take into account product price decisions with regard to OPP placement. (Tiemoury & Fathi, 2013)

Table 2. Advantages and disadvantages of shifting OPP forward and backward in value chain (Olhager 2003).

Advantage/OPP shifting	**Shifting OPP backwards**	**Shifting OPP forward**
Lead time	- Longer delivery from order	- Faster delivery from order
Delivery reliability	- More likely to have delays due to material availability uncertainty - Less possible inventory	- Less likely to end up in delay with materials - Increased inventory levels with finished goods and work-in-progress goods
Product range and customizability	- Decreased limitation on product specification - Fewer possibilities to standardize products and production	- Increased limitation on product specification
Production price and capital investment	- Higher production cost due to customizability - Less likely to have obsolete inventory on stock - Relying more on forecasts	- Lower production costs with economies of scale and prefabrication - Better optimised production - More likely to have obsolete stock

Shifting the OPP has significant impacts on the nature of the entire company operating processes. Olhager (2003) describes the OPP shifting with competitive advantages separately for forward shifting and backwards shifting. In this context, shifting OPP forward means to shift the customer involvement closer to the goods or service delivery and shifting backwards closer to the engineering and design process. The major advantages in forward shifting OPP are production optimisation and reliability and reduced lead time. The reliability and optimisation relate to the fact that the further OPP is pushed in the value chain,

the more accurately the product specifications are known. Also, pre-fabrication can be made possible with the products. Lead time is reduced from as there are less value chain phases that need to be accomplished after OPP. The disadvantages of shifting OPP forward are reduced level of customization, reduced customer knowledge of the production processes and product details. The main factors and effects have been collected on table 2. (Olhager 2003)

Customer order fulfilment delay risk and inventory risk, need to be evaluated and investigated case by case, since there are aspects that change with the industry. Cost risks need to be taken into consideration when thinking about MTS, MTO or hybrid MTS/MTO solutions. Order fulfilment risk rises as the OPP is moved backwards in the value chain, as there are more activities that cannot be done in advance. In having the OPP in a position that is further down the process, the level of standardization increases. In certain circumstances, increased level of standardization may open a possibility to take advantage of economy of scale and mass production to stock and hence push the production unit cost down with mass production (APEC, 2010). Similarly, shifting the OPP forward raises the amount of capital that is invested in stock, and depending on the industry, the demand fluctuations can make some stock obsolete. (Tiemoury E.& Fathi M., 201; Olhager, 2003)

3 Case company and the Marine unit

In this chapter, the case company is briefly introduced. Also, the product and processes are briefly described and modelled. Furthermore, the department that is conducting the thesis is introduced. Since the company is a publicly listed and exchanged company, the thesis will not introduce the products in special solutions with other than brief detail.

3.1 Case company

The case company is heavy industry company listed in the stock exchange, that designs, manufactures, delivers, and maintains different types of lifting and moving devices mostly for people movement. The company also has automatic building access solutions available, as well as equipment maintenance services and modernization capacities. The company's offering consists of volume based standard lifting devices and some major projects that can have significant variations on the lifting solutions. This is possible since the offered devices can be engineered to a specific locations to serve the intended use in the best way possible. The case company operates globally, and the organization is present in over 60 countries with over 60 000 employees in total.

The case company is one of the global leaders in their market. The business is divided into three categories: new equipment business (54%), service equipment business (33%) and modernization business (14%). According to the company's estimates, in newly sold units, the market share was about 19 percentage globally in 2020. The main market areas for the company are China and EMEA. The company is known for the high quality of their products, and often customers are willing to pay up a premium for that.

3.1.1 The Marine unit

The company has many different divisions that serve a specific market area. One of these specific divisions is the Marine unit where this thesis was conducted. The Marine unit produces lifting devices to the maritime environment inside different types of ships and

applications. The unit is collaborating heavily with some of the biggest shipyards and cruise operators in the world. The shipyards include Meyer Werft, SWS, Chantiers de l'Atlantique to name a few. These combined construct cruise ships and other vessels to all the major cruise operators in the world. The Marine unit strategy is to do business mostly with bigger cruise ships. Lifting devices are designed and supplied by this unit individually for each ship and can be found on some of the biggest cruise ships sailing to date.

In the Marine unit, there are separate Marine specific teams working with each business area that the company has. Globally, the Marine unit has about 75 employees located mostly in Europe, in the time of writing this thesis. The Marine unit is currently expanding to establish a more solid presence in one of the major shipyards in Europe. Lifting devices are most often the ones that are built inside a cruise ship or a ferry ship and are specifically designed for these applications and specific ships. The custom engineered product makes the product flexible for the customer requirements and increases the customer value on the product, while still maintaining the quality of the product.

The Marine products have certain specific features that make them different from other division products. These are for example additional safety features and additional certificate requirements. The additional certificate requirements make the material supplier selection process more time-consuming, and close collaboration with classification societies is mandatory. Also, some operational modes and additional programmed features are automatically added to the product, to ensure user and equipment safety on board. These additional features contain for instance a sensors to stop working if ship pitching goes over a certain point, the lifting device will automatically park itself on a certain predetermined deck. Also, some lifting speed monitoring devices are added in the Marine environment.

With the Marine unit, the nature of the business is heavily focused on projects due to the ship's complete construction occurring only once in its lifetime, excluding modernizations. The only business area which is not based on projects is the service business, conducting maintenance on the vessels on a regular basis. On the new equipment business where this thesis focuses on, the Marine projects last one and a half to three and half years, depending on the size and complexity of the ships. All the projects are unique with various challenges, and they can contain as many lifting devices as the ship can fit. The number of lifting devices contained in one project can vary from one piece to over 50 various lifting units at the time of writing. This can change as the aim for the cruise shipowners is to steadily increase the

size of the ships. As a subcontracting company for the shipyards, the lifting device assembly schedule is very much tied to the ship's block outfitting and lifting schedule. This makes scheduling especially challenging since warehousing facilities are most often very limited and only certain materials are required at a certain time. This highlights the benefits and disadvantages of LEAN and Just-In-Time deliveries from subcontractors to shipyard.

Due to the schedule being heavily tied to the ship's block schedule and outfitting schedule the Marine projects require significant amount of supply and project management lifting device delivery splitting into delivery groups and schedule management, cost management and quality and risk management. It is typical that a single lifting device is divided into six to nine different delivery groups. Therefore, correct scheduling and careful planning and risk management plays a significant role in Marine business.

3.2 Current process overview on the lifting device value chain

The basic value chain process, how Marine business works, is presented in the below presented chart 1. In the flow cart, the value chain begins at the point where a shipyard makes a request for offers to various suppliers. Offers are then sent by the lifting device suppliers and negotiations begin on the pricing, scope, and schedule. If the case company is chosen to be the supplier, the OPP takes place. Also, at this point, the scope of supply is determined. Since the engineering phase is still to come in this process, we can reliably say the manufacturing strategy in use is Engineer-To-Order.

From sales negotiating, rough estimates on the schedule are made and the design process begins by making technical general arrangement drawings referencing the ship's design. The sales have already agreed on the handover dates for the equipment in the sales contract. The general arrangement drawing (GA) preparation process starts for other engineering such as cabin and signalization on the side. Descriptive technical drawing containing only the main features of the devices (M-drawings) are made for the customer. After receiving the GA and M-drawings, the customer gives feedback for needed changes or approves the drawings as good for use.

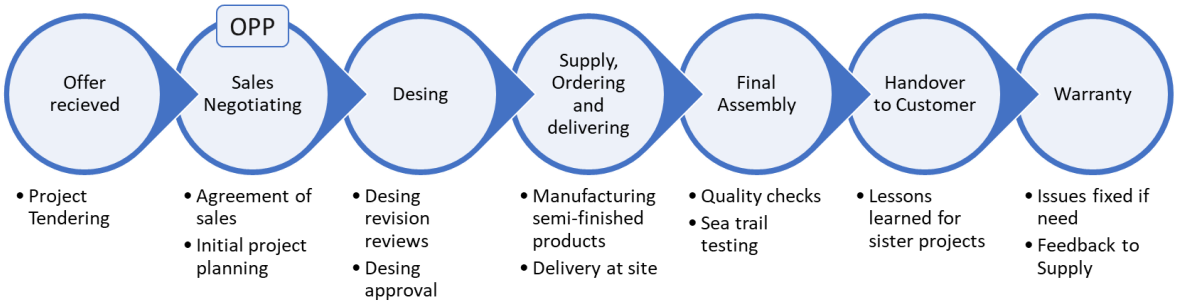


Chart 1. Flow chart of Marine lifting device projects.

It is worth to note that the design process is ongoing simultaneously in the shipyards and within the Marine unit, which can easily cause inconsistencies. General layouts and dimensions are usually clear at that point, but detailed drawings are available only later. When the drawings are done by the case company, they are submitted to the shipyard to be approved or commented on further. If the shipyard finds inconsistencies in the general arrangement's drawings, they give feedback to the project manager who inform the design team, and the drawings are corrected. From this point, the process has quite noticeable agile project management features. In the projects, these submittal and correction loops can take please multiple times, and this highlights the agile features of the process. According to the Marine Engineering unit manager, it is not uncommon to have four to five of these revision rounds in a single project. This is the case for ships that are first in their series. The following ships typically have fewer revision rounds in the layout design phase. These are included in the sales contract and tender letter. In the case company's original offer, there are multiple of these correction loops included in the offer, so the product will be tailored to the precise customer needs.

After the design is final and everything is approved by the shipyard, the ordering phase begins, and the process comes back to being closer to a traditional construction process with suppliers and sub-suppliers. The materials are scheduled with JIT strategy to minimize the need for warehousing and suit outfitting schedule of the ship blocks. This is critical since the very limited warehousing facilities at shipyards generate extra costs and generate the need for more accurate site management in a LEAN-based environment. LEAN management is mentioned as one of the cornerstones in the entire company strategy.

In the outfitting phase, half-finished materials are assembled into one or more lifting devices. With some projects there are some semi-outfitted structures which make the installation faster in the shaft. After site assembly, the devices are tested, and their quality is checked. The faster installation and finishing of the construction makes it possible to have construction time usage moving goods and people in the bigger ships. This increases the efficiency on board during construction. After this, the product is handed over to the shipyard and to the customer. Following the handover, lessons learned from the project are collected, and similar topics are tried to be taken into account on future projects. This is especially important with ship series that will have a following ship in the series. At the same time, warranty period begins, and new issues are solved by the warranty team, if there are any. The length of the warranty period is always predetermined in the sales contract.

These steps are also presented in appendix 2, where the milestone used in the case company are listed and connected to their phases on projects. Sales is represented with 0b and 0c. Design phase milestones are 1b, 1c, 2 and 2z. Supply functions take over in the milestone 3 and 3s where the required materials receive the no-return-point (NRP). The NRP is milestone where the specification is frozen, and the orders will be posted to the suppliers and the material will be manufactured and delivered to the requested address with correct schedule. This can also represent the delivery to outfitting the semifinished structures sub-supplier. There are special arrangements with the structure deliveries to shipyards. 4 and 4c are installation milestones that occur at shipyards before milestone 5 as the handover to the customer.

3.2.1 Winning factors and current success factors in Marine projects

In the Marine unit, there are certain winning factors identified. Most recognized factors from customers are equipment and the Marine unit’s quality and reliability. Both factors are identified for all functions, new equipment projects, equipment maintenance services and equipment modernization projects. These factors are supported with heavy presence in most of the shipyards and constant co-operations with the shipyards. The local teams also have support from the management and are aware of the limiting factors occurring from the technical side and who aim to communicate as openly as possible. This also allows the Marine unit to be involved in multiple projects in the same shipyard. The local presence

makes the Marine unit more flexible in the bigger shipyards. Work can be allocated better between different projects if targeting is needed.

In the Marine unit, there is a constant will, to develop the services by piloting different equipment solutions on site with real live projects. With this, the customers can have hands-on experience in how the solutions can improve the user experience. The development is done so that the risks are managed and observed case by case. An example for the development actions is touch screen operated cabin operating panels (COP's).

In winning projects, a major factor is also, that the case company has an excellent track record in previous Marine projects. There are many challenging projects delivered with great success, covering all types of ship related lifting devices. As an example, some of the biggest cruise ships have the case company's products in active use. Also, there is significant effort put into maintaining customer relationships, since the industry is composed of only a handful of major companies that can afford the large investments that building a cruise ship requires.

Some of these factors are directly presented as project success factors. Team integration and experience mitigates the risks and makes identifying them easier with a well-established and present site organization. With the strong presence and multiple simultaneous projects, the team is flexible and lessons learned from previous projects can be taken into account. Also, since the presence has been developing over time at sites the project manager (PM) experience has been developing critical limitation and resources are well known. In regard to the identified project success factors, HR and PM aspects are well taken into account and enforced in the Marine unit, as mentioned above.

3.2.2 Challenges within the Marine business in general

Although the Marine Unit has good and relevant references and multiple winning factors compared to other companies on signing projects, there are some major challenges in the maritime environment. This is highlighted especially during multiple global supply chain disruptions that effect the project profitability heavily. Most of these challenges are long lead times and long contracts with customers. It is very common that the product's final deliveries occur after two years from signing the sales contracts. The extra-long lead times are a feature of the ETO process that is used as the manufacturing strategy. Although ships are usually in

manufactured in series, the engineering part cannot be passed due to some changes and lessons learned in between ships. This raises the cost risk significantly for projects.

In addition to long lead times, there is often little-to-no possibilities to affect the shipbuilding schedule without penalties. As there is a heavy engineering process, all project's variations are more than common before specification can be frozen to start the ordering process. These variations can sometimes be charged from the customer, but some are internal findings that the project just must cope with. Often this results in engineering that needs to be carried out in a hurry, under a heavy pressure. This causes difficulties in the risk identification, although this has been accounted for by longer lead times. Nevertheless, this highlights the need for constant risk monitoring. It is also typical for the variation request to arise from the shipyard during the ordering process. This requires a lot of attention from the managing team to organize special deliveries. This makes it harder to manage the final product quality and have a full understanding of a clear goal for the project, as the specification changes and the initial specification validity cannot be taken for granted from sales to the final delivery.

The long contracts also cause the risk of raw material price fluctuation on the sub-suppliers, which have the opportunity to reflect the price increases to the case company due to a much shorter lead time. This has been quite visible during the Covid-19 pandemic and sub-supplier component shortages. Quite often the situation in the case company is, that there are only a handful of certified suppliers for SL, who can supply the required materials. The price range for bids is often quite small and there is not much else to do except to choose the lowest feasible bid. Adding a new competing supplier required the company research and approval. There needs to be special agreements regarding traceability and other factors that the company material management needs to check and agree on.

The limitations can be avoided, by changing the scope of a certain material from SL to FL. This requires additional work and change management with invoicing and special specification marking that, which can push the costs up. This causes the scope changes to be done only on rare occasions and even than with great consecration. Furthermore, a suitable supplier needs to have available capacity and quantitation need to be requested before such actions are taken into consideration.

In the current model, managing costs is very difficult without compromising the quality. Due to this, constant cost savings are attempted in the Marine. Lowering quality is not an option,

and the case company has separate quality management personnel employed. Also, quality is named as one piece of the current strategy along with LEAN functions, sustainability, and safety.

4 Marine project: lifting device design

As stated earlier, in the case company's Marine business, every single the lifting design solution on board is custom designed to fit and serve an individual ship and customer need and requirement in the best possible way. With this engineering, the customer value can be increased. Analytical methods are used to model out the requirements and optimisation possibilities to give the best customer experience on the ship. These must take into account the frequent use of passengers boarding, crew moving goods to dedicated sections and decks and many other factors. The analysis results require tailored fitting for the lifting devices and is especially highlighted with bigger cruise ships. It also is increased with easier compatibility to the ship design.

Special attention needs to be taken with big cruise ships, but smaller ships can have their own challenges. As the ships get smaller, for example the space limitations come into play and make restrictions for the design. When planning the functionality and calculating structural strain forces, there are a multitude of things that need to be taken into consideration in order to develop the best solution for the layout and placement.

4.1 Engineering on Marine projects

In the case company's Marine unit, two different types of lifting devices are engineered and produced. One of these types is a type meant for the ship passengers to use, and the other is a type meant for the crew and other service actions. With the Marine unit, the passenger lifting devices are called PLD's and the other ones are called SLD's. With these lifting device types, the key differences are in the placements in the ship and the cabin equipment. The PLD's have typically more decorative interior design and materials than SLD's do. Also, SLD's often have features the PLD's do not have, like ladders placed in the cabin, for instance.

For both lifting device types, the design, and engineering that is needed has been divided into 12 different engineering categories, which all have their own specialized engineering departments. These include the Marine unit internal engineering (layout/GA) engineering,

supply management, listing engineering, tender engineering, and chief electrification engineering) and other engineering (machinery, software, mechanical, signalization, electrical, cabin, door engineering) conducted in the company. The engineering that is done outside of marine is referred to as external engineering in this thesis. As the different design categories of engineering departments are dependent on each other, they need to have a certain starting reflection point that is the same for all departments. This ensures that the engineer solutions work in the lifting device and support each other.

The connecting point for the design organization is layouts and general arrangements. As in the Marine units the design begins from the ship's general arrangement, that gives base for the lifting device arrangement, it makes a good point to reflect the other designs. From the layouts for instance the cabin dimensions are predetermined and from that the cabin design can see that the cabin frame type is correct, COP has the correct location. Also, as overall electrical design and connections go hand in hand with layout, the electrical design gives base for signalization design. As electrical design and layout design are base for other design categories, these are internal to Marine and there are few marine specific chief engineers who have specialized working with ship designing.

As the lifting devices are assembled locally, the engineering categories design these semifinished products for the finished product. Some of these semifinished products take more time than others. For instance, the doors are quite simple to design compared to signalization devices and cabins. Depending on the product complexity, there can be a chief designer, or a lead designer allocated to the project. Usually, lead designer is allocated to a less complex project than the chief designer. Both are still accountable for the design's functionality and seeing that all necessary requirements such as the U.S. Public Health Service requirement is fulfilled. The chief of the lead designer often can allocate the less demanding work to other designers if needed. The designed parts are then built and manufactured according to the design. Some more complex pieces have separate internal manufacturing drawings made, as the manufacturing in the heavily machined factory is made smoother and easier.

Although the individual design is needed among the lifting devices, the company faces an issue that of the lifting devices intended for crew use have similar or even same overall design. There are certain features that occur in almost all SLD's, and the major changing factors are travel that the lifting device needs to be able to serve, overall dimensions. The

differences with these are other minor, such as handrail type or material. These differences are typically a relatively small compared to PLD versions. The biggest difference causing factor comes from the requirement on some ships to fulfil USPH requirements which changes the requirements on some materials such as cabin floor, handrail, and roof types. The needed modifications are mostly reflecting the cabin interior.

4.2 Required customer documentation on projects

In every Marine project, there are certain certificates and documents that are always required by the customer and shipyards. These are required for the design approval on the shipyard side and also, in order to complete the detailed GA drawings in this the shipyard. Class approval requires certain documents, and this is highly dependent on the class, as some require more detailed descriptions on the engineered solutions. In the appendix 3 there is an example list of the required quality documents are presented.

From the appendix 3 it can be noted that most delivered documents are technical drawings that are done individually by the engineering team. The majority of the engineering work directed to making GA drawings and electrification drawings. These are prepared by the Marine internal chief designers for layout and for electrification (ELHW). Signalization drawings are prepared with close collaboration with ELHW CDE.

In addition to technical drawings, there are quality documents and certifications typically required. Certificates can be either batch related or general certificates. These are taken from company internal sources or are separately requested from the suppliers. With quality documents, there are certain quality gates in place where most of these are created. These are for instance the factory inspections where the cabin is inspected that it has been built according to the drawings that have been submitted and approved by the customer.

All these documents are needed and need to be gathered by the project management as in the end they are the responsible parties towards the customers. The project manager applies for the class approval for the engineered lifting device solution. This was done as a part of the entire ship’s class approval and registration under a certain flag.

5 Previous projects cost analysis

In this part of the thesis, a handful of project costs are analysed to get a better understanding on how the costs have been distributed within the previous projects. Analysis is done based on data from projects that have been in the Marine unit and have been closed already. This is because before the project is officially closed, there can still occur issues or variation in the financial side. This is the case with warranty issues, for example. In the case company the costs are divided into two parts: Front Line (FL) and Supply Line (SL) costs, although both work in close collaboration with each other, with an open-book management. In the case company combined FL and SL costs are referred to as full chain costs.

This thesis focuses on smaller Marine project costs. Small projects have been defined so that the project contains one to five lifting devices in total for the project. This is due to bigger cruises often needing additional steel support on the hull itself, and the project's over all complexity increases simultaneously with increasing number of lifting devices. Also, the supporting steels can have significant differences and can impact the costs very heavily. The requirements vary according to the individual ship's design and engineering solutions.

5.1 Project full chain costs in the Marine unit

Marine project cost data has been received from the case company databases. There have been multiple tools used when collecting different kinds of data that have been combined to represent different cost categories. The data contains full chain costs from 25 different projects, with each including one to five lifting devices. Overall, the projects contain 63 different lifting devices. 23 of these lifting devices are for service use and 40 are used with passengers.

As mentioned earlier, the projects that the data analysed is based on is from closed 1-5 lifting device projects. From these 25 projects 40 percentage are two lifting device projects and 24 percentage include only one lifting device as is presented in table 3. With these numbers presented, it can be concluded that the data presented is more reliable with a one to two lifting device projects. Since there are only two to four projects in the three to five lifting

device projects, the data might not present the actual situation in full detail and this needs to be considered as directional while observing the analysis results. To get a completely accurate picture more data would be needed, but unfortunately that is not available since there is only the included project data in tools used today in the Marine unit. Nevertheless, these projects have been completed within the last decade and no more have been under construction. This also indicates that it isn't that common to have projects with three to five lifting devices.

Table 3. The amount of different sized projects observed in the analysis.

Total number of lifting devices	**1**	**2**	**3**	**4**	**5**
Number of projects	6	10	2	4	3
Per-centage of projects with x lifting devices	24 %	40%	8 %	16 %	12 %

Both FL and SL costs can be broken down into different general components, but this varies from project to project, as the scope can be different between SL and FL on other projects. The cost structure borderline is not the exact same with all the projects due to some special solutions that require some special arrangements. For instance, some PLD cabins have one set of doors, others have two and these might be oriented with doors on A-side and B- or D-side instead of C-side. The variations with every project are defined in the scope of supply, which is agreed between FL and SL. Also, the requirements vary across the ship types, where the lifting devices are implemented. As the projects include small expedition ships, ferries, and even a military ship, the analysis results need to be taken as directional estimates instead of absolute facts.

The door sides have been directed so that with cabins having only one door, the door is always on the A-side and the general rule is to have the A-side oriented down in the technical drawings. The naming of the walls is alphabetical and goes around the cabin from A to D going counterclockwise, as is presented in figure 1.

In general, the FL costs on projects include sales management and support, project management and site management, local assembly of the lifting devices from the semifinished products, and local quality management costs. FL also provides some small lifting devices like handicap platforms and dumbwaiters. Due to the lower complexity, these

devices do not need external engineering and can be supplier with less complex processes. Some special arrangements might also be needed, such as local warehousing, which is covered by FL, if not agreed otherwise with SL. FL costs also include smaller lifting devices that are subcontracted from external supplier that serve only few decks or move small amount of goods or are used to assist handicapped individuals.

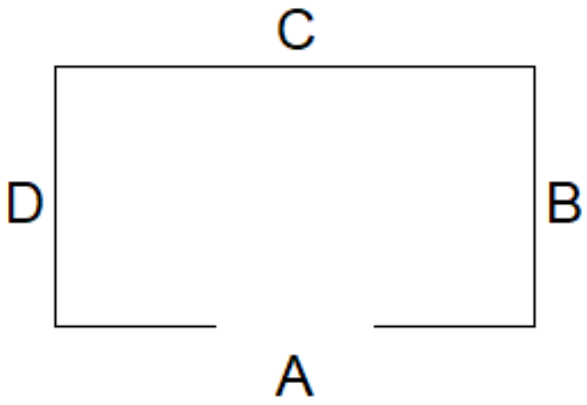


Figure 1. Lifting device cabin wall naming and orientation in the case company.

SL costs represent most of the lifting device materials from different suppliers, different line organization engineering, supply planning and management and logistics costs. Lifting device materials and engineering are divided into nine different line organizations which produce the semifinished components assembled at site by FL. Engineering department produces the essential technical drawings and calculations. Supply management is calculated in engineering when observing the total SL engineering costs.

The observed costs that have been collected from case company data sources represent engineering costs and supply line material costs compared to project costs project. This data is shown in chart 2. In chart 2 these costs have been divided into 5 groups depending on the number of lifting devices in projects. From the chart 2 we can see that the engineering costs are typically about 10 to 20 percentage of the total on these projects. In these project the number has been closer to 10 to 15 percent in the analysis. Also, material costs in the supply line cover 35 to 45 percentage of the costs in projects.

From the data presented in chart 2 it is visible that the project size does not have a significant impact on the engineering costs that will be generated on the project per lifting device. On the other hand, the material costs show more variation. These percentages range from 30

percentage to 60 percentage, but it is important to remember that the data is calculated from a relatively small number of projects, which have some variety. In addition, some projects have been delivered and purchased during Covid-19 period, which has heavily affected material prices. The engineering costs have had a smaller impact from the pandemic as the hourly rate changes only yearly and fluctuations have been small. The total number of projects containing 4 or 5 lifting devices sum out to only 7 projects in the data. Also, from the three projects that are presenting the cost data, two projects are sister ships and have had no changes between the ships, which has driven the overall costs down. This causes high possibility for inaccurate result on a detailed level. The only reliable out take from this data is a higher level out take that on average the SL is around half of the costs and engineering cost about 10-20 percentage of the costs.

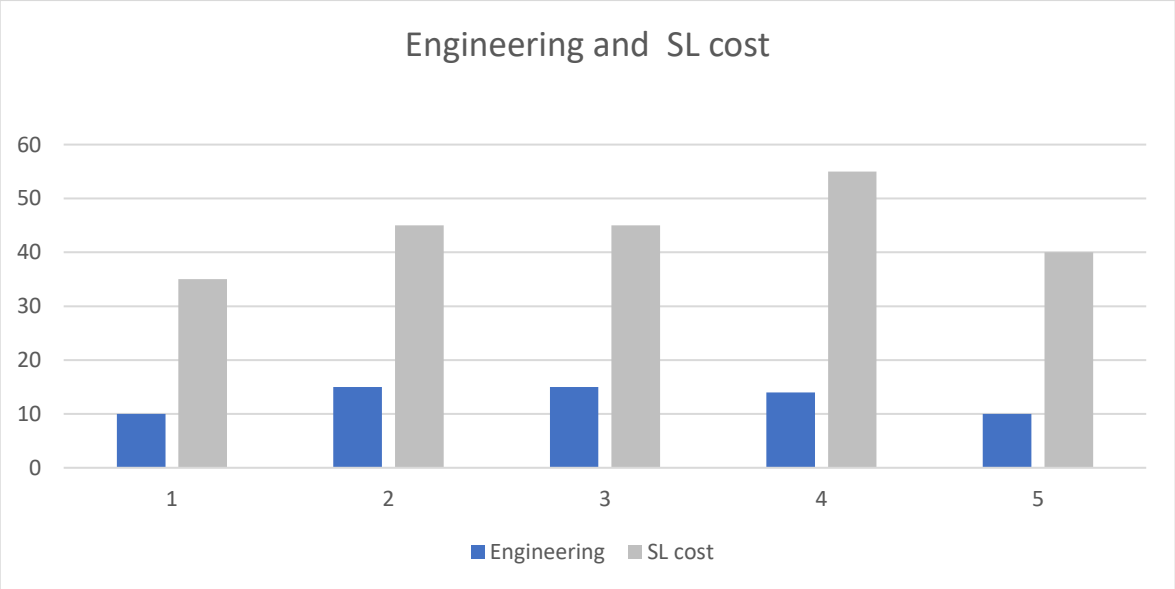


Chart 2. Engineering and SL costs compared to other costs on projects

To conclude this the supply line costs, including engineering costs, material costs and supplier line mark-up cover on average about half of the costs on a project. The rest of the costs are covered by sales, project management, and most significantly outfitting, local installation and lifting the lifting device on board a ship. There also might be costs related to temporary warehousing, although the company aims to have materials on site with just-in-time principle.

5.1.1 Engineering divided into different engineering categories

In this previous observation, the actual engineering costs in all projects used in above analysis are presented and analysed in more detail. The projects included are the same ones, but this time the data is based on ERP system confirmed activities. All the engineering costs should be generated through the ERP system, and this will provide a more accurate breakdown of the categorization and actual engineering amount required.

The case company has multiple engineering departments which specialize on different parts of the lifting devices. These engineering departments are cabin, electrification, door, layout and general arrangement, chief electrification, listing, machinery, mechanics, signalization, software, supply management and tender engineering.

On Marine projects in general, some of these engineering departments are requested to generate two sets of technical drawings. The first set of drawings are called M-drawings, which are submitted to the shipyard and customer to be approved. M-drawings most often contain drawings from the cabin, COP, signalization devices and from landing doors if special doors are requested. This is a requirement from the customer side, and it is the place where the customer accepts the product details prior to production. If needed, these drawings will have multiple revisions in order to fulfil the customer requirement. These can be for example Signalization M drawing showing the landing devices and their details.

After the M-drawings have had customer approval, the second set of drawings are created at the same time as the ordering is occurring. The drawings are called manufacturing drawings, and they show more detailed instruction on for instance cabin wall welding. Manufacturing drawings are purely for internal use and are done separately for each individual lifting device part that is ordered through custom engineering. Both sets of drawing need to be consistent with each other, and there are quality gates for monitoring these.

GA drawings differ from this, since it is important to match the lifting device GA to the ship GA’s. The M-drawings are made in the early phase and are submitted to the shipyard. The general arrangement drawings contain quite many revisions, and in some projects five revisions are included in the tender letter before variations are invoiced from the customer. It is common that the ship GA is being processed and done at the same time as the lifting

device GA. This most often causes the need for variations and the need for flexibility, especially with the first of the series ships. The flexibility is one of the winning factors on sales to the customer.

In the Marine unit, it is common to have a chief design engineer (CDE) from the various engineering departments. Some of the CDE's are Marine internal and are always used in projects and some are optional depending on the level of difficulty and customization in a certain project. These Marine internal CDE's play a more significant role in the project since they cover a larger responsibility if the CDE would be external to Marine. Unit internal engineering includes supply management, listing, layout and general arrangement, chief electrification, and variation tendering. This accounts for 56 per-cents of the total engineering required on projects, as presented in chart 3.

Different semifinished products in the project require different amounts of engineering, and the variation with these depends heavily on the customer requirement. The average distribution of a project's engineering is shown in Chart 3 for the same projects that were included in the analysis earlier**.** The chart 3 represents the engineering based on actual hours spent on the project that have been confirmed in the case company ERP system. The chart 3 illustrated that the highest amount of engineering is taken by supply management (22%), layout and general arrangement (17%) and chief electrification engineering (11%). One of the explaining reasons is, that why these engineering categories have the highest portion of engineering is that Marine CDE's are involved in clarifications to external engineering. Although some engineering departments might have a dedicated CDE, internal CDE's provide information and engineering instructions for the external engineering, such as cabin and signalization engineering. Furthermore, revisions in layout and electrical drawings have a significant increase in the internal Marine unit hours spent on projects. In the supply management side, the complexity produced by quite highly distributed supply chain and quality management with FL produces easily additional engineering hours.

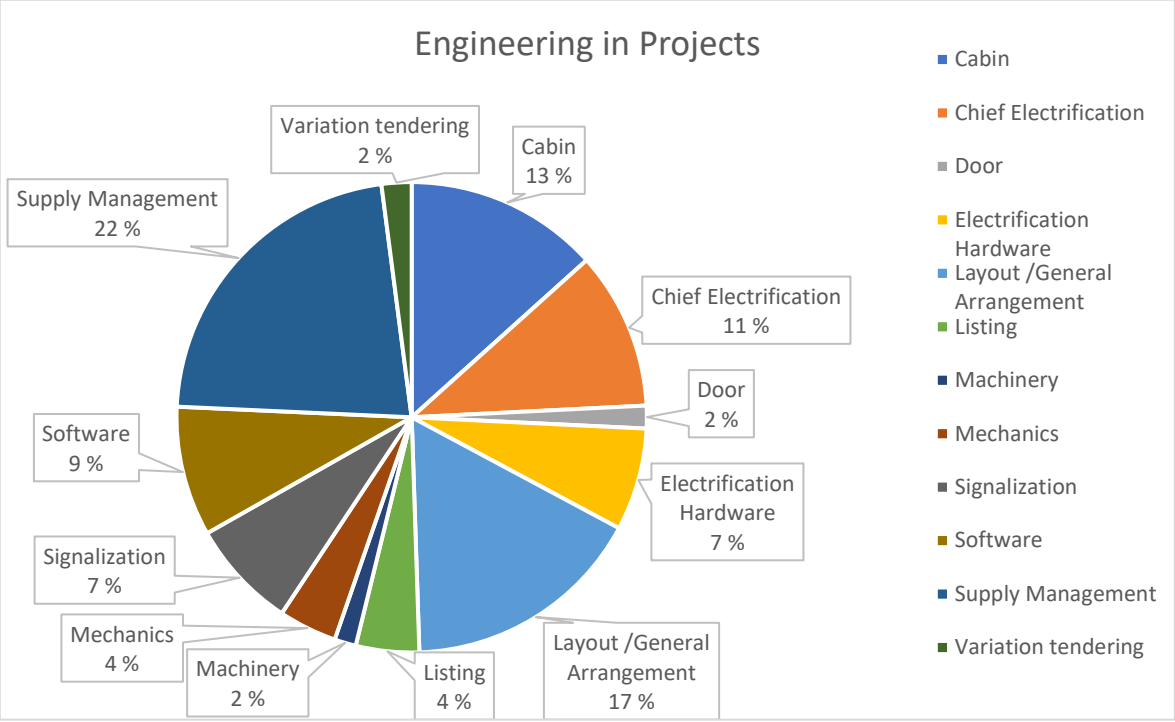


Chart 3. The average engineering spread to different engineering departments in small projects.

As the engineering activities are monitored in a company-wide system, there are separate activity types depending on the work that is done on the engineering departments. With the activity types, it is easier to monitor what kind of work and costs from the work have been allocated to different projects. In table 4 and table 5 the ERP system activities have been divided into different groups according to the activity types, separately for Marine and for external engineering. In the tables, it is visible that not all the engineering departments in marine use the activities in the same way as others. This can be observed when comparing the activity spread between layout engineering, and other marine engineering. There is a greater proportion of revision activities in layouts than with listing or chief electrification. This is the result of chief electrification engineers using only monthly activities to cover all the work that has been allocated to projects. The case is similar with supply management, as there are monthly activities that cover all project related tasks per project.

The monthly activities do not give a full and accurate picture of the engineering tasks, which causes difficulty in reporting and clarifying the work that is actually done on the project. Furthermore, the monthly activity does not take into account the engineering that is invoiced with variations. In order to make more accurate analysis, different activity types could be

used by all internal engineering tasks. Considering that, there would be more activities used, the manual work would increase, the changes result in slightly higher number of hours spent on projects. This assuming that the person conducting the work would create and confirm the activities by themselves after specific tasks. Nevertheless, this would be the price for more accurate reporting. As cost savings are searched from the projects overall, this could give future projects opportunity to critically see the actual spent engineering hours. Further research and profitability analysis needs to be done separately before desertions on piloting task-based activities can be considered in future projects.

Table 4. ERP system activities and activity types presented per Mariner internal engineering department.

Marine Engineering	Layout	HW specs	Listing	SM	TE
Engineering work	61 %	98 %	98 %	100 %	100 %
Clarification	13 %	2 %	0 %	0 %	0 %
Engineering revisions	26 %	0 %	2 %	0 %	0 %

Table 5. ERP system activities and activity types presented per external engineering department

		SIGN						
Exteranl Engineering	Cabin	Sign	COP	ELHW	SW	Door	MECH	MACH
Engineering work	49 %	18,9 %	34,7 %	89 %	97 %	66 %	93 %	81 %
BOM- engineering	9 %	0,0 %	7,2 %	0 %	0 %	0 %	0 %	0 %
M-drawings	24 %	12,2 %	15,3 %	0 %	0 %	16 %	0 %	0 %
Clarification	4 %	0,4 %	0,7 %	7 %	0 %	18 %	6 %	19 %
Engineering revisions	15 %	8,2 %	2,2 %	5 %	3 %	0 %	1 %	0 %

With layout engineering, there are revision activities describing the amount of work that has been allocated to changing the layout/GA with either FL request or SL request. In addition, the clarification activities contain work that is needed to give clarification in cabin, door and other engineering as has been necessary. Layout clarification work included preliminary work for M-drawings, such as creating guidelines and instructions for cabin engineering.

With external engineering the activities have been allocated with more detail on the table. There is Bill of Material engineering (BOM), M-drawing engineering or customer documentation creation, clarification, and revision engineering. BOM engineering is occurring in only some departments, which are cabin, signalization, and electrical engineering. With electrical engineering, BOM engineering is included in the regular

engineering work and is not separately on ERP system BOM activities. M-drawings are requested separately from cabin, signalization, and door engineering.

5.2 Current project cost savings

As LEAN is a major part of the company strategy and in the company, there is a great pressure to seek cost savings and more efficient work potentials. This cost saving mentality is also visible in the Marine unit. There are multiple ways to have cost savings, and there are many actions and development projects in place to enforce this. This thesis is one of the actions seeking savings. Also, additional pressure has been received in between 2019-2022 from global supply chain disruptions. The long lead time projects with multiple year contracts face a lot of challenges due to material availability issues and price increases.

5.2.1 Material sourcing

The cost analysis shows the material costs cover 32 – 54 percentage of the total costs on the smaller projects. These costs are mandatory and cannot be reduced to zero since some material needs to be deliverd in order to build a lifting device, but some cost savings might be gained to request quotations for certain project specific materials. Currently, there are a little less than 120 different certified material suppliers. These suppliers supply semifinished products to SL, and all have their own more or less complex sub-supplier networks. These are completely supplier specific. Material price comparison between suppliers needs to be conducted, and it is worth it to see if the country of origin can bring the materials costs down. In the case company materials purchased from China have typically been cheaper than materials purchased from Europe, especially when talking about bigger volumes. This is often the case even with the logistic costs considered.

From the 120 certified suppliers, some are also company internal suppliers. From the different requests for quotations (RFQ’s), the price points can be discussed and the pricing between these can be compared head-to-head with different suppliers. As the project specification is unique for every single project, these are asked more for the most valuable components uniquely to each project. As the process stands, there needs to be some input

from engineering team supporting sourcing in order to have the RFQ. There is another development project ongoing related to sourcing, so this thesis will not address this topic in greater detail, accept acknowledging that this kind of action is occurring on all projects in the Marine unit.

5.2.2 Engineering savings and potential standardization

As material savings are chased with sourcing actions and FL has developed and fine-tuned the installation processes to be as efficient as currently possible, engineering is an area that needs to be observed with more precision. Attention has been put to the installation effectiveness, so that the semifinished materials do not need to be touched more than necessary. The goal is that the materials are installed fully only once by the installation workers, and they would not need additional adjusting. Also, building scaffolding is not necessary as for instance cabin roof level position can be adjusted by driving the cabin to a certain needed height. Furthermore, heavy participation in the block outfitting phase helps the installation more efficient compared to conventional construction methods. This although zone outfitting cannot be fully utilized as lifting device spread across ships. Still lifting device grouping can allow the installation attention to be focused more on one block at the time in optimal circumstances.

The analysis shows that about 10-15 per-cent of full chain costs come from engineering, so the cost needs to be carefully analysed so that engineering hours can be decreased from the current need. The monetary value of 10-15 per-cent per project is a significant value and affects heavily on small projects that are observed in the thesis.

The idea of a standardized lifting device has been presented to cut engineering hours and costs. With this saving action, the solution would require that the projects engineering solutions would be done one and the same engineering solution would be re-used in then following projects. With this solution, the OPP would be shifted forward, and the manufacturing strategy would fundamentally change from ETO to MTO.

6 Marine projects standardization and shifting OPP

In this section of the thesis, the OPP shifting is observed in the Marine unit. The attempt is to describe a situation where the entire manufacturing strategy would be transformed from ETO to MTO, and for this the benefits and requirements are highlighted. For this section there were meetings held with the Marine unit engineering manager, head of sales support and offering management and the senior chief designer. Their experience from the Marine environment and past projects from the past couple of decades is compiled with the cost analysis project data.

The specification has been observed through new CRM tool, that is used in order specification creation and pricing the order, where the specification modifying is going to be done in the future for all up-coming projects. At the time of writing this thesis, this system is being simultaneously piloted at Marine, with the first two live projects and one starting very soon. The CRM based tool assistance is a key element of the standard specification development.

6.1 Benefits of shifting OPP in the supply chain

Shifting to MTO manufacturing strategy requires the Marine unit to have a standard specification where all the technical factors affecting the order are predetermined and known before the customer's order is placed. As all the required materials are pre-determined, the project management is easier due to more clear goals and objectives. Also, the PM can give NRP the soonest the order is confirmed, and materials can be ordered immediately. This can make the delivery lead time shorter as the additional clarifications can be removed from the process. From the customer perspective, the specification and lifting device GA is 100 percent clear when placing the order. With this information and requirement, ship's GA could be adjusted to fit the lifting device and fulfil the classification society and safety requirements.

In the ideal situation there is no need for engineering conducted on the lifting device and the price can be lowered with this assumption. The price reduction can be close to the average

of the total engineering costs if absolutely no engineering is required. As with smaller projects the competition is very tough between lifting device suppliers, this price reduction could give the competitive advantage for order winning and higher volume of projects in the long run. As the ideal case cannot be directly applied to reality, the actual discount is much smaller and that has to be checked case by case with the engineering team.

From the customer's point of view, MTO strategy allows the goods delivery to occur faster than with ETO. This is since after order placement, engineering does not have to spend time on design as it is already available down to the finest detail. This arises as the benefit from the expense of having little to no effect on the final configuration and design.

Additional advantages that can be gained from the OPP shifting are increased ability to forecast material prices. The availability can be more ensured as it is known early on that what materials are needed and when. This decreases the risk of delays in the supply chain and the multiplicative effects further down the supply chain. This allows the installation team to have more flexibility at shipyards.

Another possible advantages in shifting OPP is an increased visibility on the financial forecasting. The forecasting can be more accurate with supplier specific material price lists, and more accurate demand and schedules known in advance. This of course requires price lists that are agreed separately with the suppliers. As forecasting is more accurate, reporting is easier and additional clarification work can be reduced. Accurate forecasting also allows operation reaction to processes, for instance using temporary inventories of certain goods in order to tie the prices of the goods on extreme situations.

Project management can also gain benefit from the standard specification. As the scope is clearer and is not changing during the project, the variation control is easier. Also, as more projects with the same specification are completed, more accurate lessons learned can be taken from previous projects and applied almost directly to upcoming projects. This needs to be proportioned to the shipyard specific factors and internal evaluation needs to be done before directly implementing the lessons to new projects. Nevertheless, lessons learned can give direction on how to be prepared and accounted for similar issues. These factors happen to be project success factors and raise the probability for successful projects.

6.2 Disadvantages with shifting the OPP forward

The imminent limitations that come from shifting the OPP is limited custom solution implementations on the lifting devices. Process-wise, the solution needs to be completely ready and cannot have any variation along the way. This limits the placements and ships where the standard solution is applicable. If there are variations occurring on the specification from standard specification, engineering is needed, and the manufacturing strategy changes to ETO. This eliminates the gained advantages from the MTO all together and might even cause projects to be sold with too low pricing and shrink the margins below acceptable levels, even to unprofitable projects.

In MTO, the clear specification needs to be already handy in the sales negotiations. All the dimensions, documentation need to be clear before the order is booked in the Marine unit. Also, the customer needs to be aware, that suddenly occurring variation will bring extra costs that need to be charged separately and will most likely postpone the site delivery. This can affect the installation and the final delivery.

As a project success factor, the flexibility sales wise is more tied up. As more features of the project are tied up, the less there is room for negotiation. Also, as the price is defined by the materials and manufacturing costs, the only point in the price that can be pushed down is the profit margin. There are no additional features that can be added without significant increases to the price. Also, the presentation of the offer needs to be more strict, as the specification factors cannot change. These are requirements and conditions in order to be able to implement MTO manufacturing strategy.

7 Standard specification and ordering process for the standard SLD

For the purpose of changing the manufacturing strategy from ETO to MTO manufacturing, a standard specification needs to be defined. After the specification has been defined, other factors such as price and estimated lead times can be determent based on the determined factors specification details. The standard specification is based on the company internal data analysis and observed trough with engineering and sales support. The lifting device technical features are also observed. The specification is made in the CRM based specification and pricing tool as an example. Some of the choices in the specification are based on the closed project specifications, when these have been compared and analysed, for instance which is the most used cabin weight capacity.

It is typical for PLD's to have special decorations and overall aspects that are visually more pleasing to the eye and to a paying customer. The cabin walls are often covered with laminates from the inside, floor materials can be tile or vinyl instead of stainless steel. Additional attention has been put to the lighting with special roofs and the operating panels may have touch screens embedded into them. All these features are special and need additional engineering. As these features are not present with PLD's the specification included is only for SLD's.

7.1 Standard SLD specification

The analysis shows that the most popular lifting device capacity is 1500 kg. Also, the lifting devices are divided close to in half in two types of devices: model 1 and model 2 devices. The key difference between these lies on the machinery and electrical hardware positioning. There are other differences also, but the mentioned factors are the most notable and significant varying factors. In the product model 1, there is a separate machine room that needs extra space from the ship. The machine room placement often causes the need for special bed plate designs, which can cause issues. In model 2, the machinery is located inside the shaft. Similarly, electrical hardware is attached to the wall of the shaft and quite close to the top-most served deck.

Since the variable features are more limited and manageable with model 2, 1500 kg model 2 lifting device has been chosen for the starting point. A finding from an interview with a cabin chief design engineer also supports this choice, as other units in the company have only model 2 devices as in the standard offering. The initial price difference between the two types of devices is quite small and not significant. Hence, it is more beneficial to have a model 2 lifting device on the base of the standard specification. This decision also excludes the need for machinery design completely, as it is most often used to design special bed plates and coloured special machineries. With this limitation, there are a couple of options for the cabin dimensions, and the chosen measurements are (width) 1,5 m x (depth) 2,2 m x (height) 2,1 m.

In this example specification, there are 8 decks that have doors and are all served by the lifting device. The number of stops is a variable feature which is not possible to be standardized. This can be seen from the Appendix 2 where deck heights are presented in distances for the projects included in the same projects as in previous analysis. There can be decks that do not have landing doors in between served decks at all, and these are not served by the lifting device. The data shows that the most popular number of serviceable decks is 6 (41% of all lifting devices observed). The specification is still good to make so far with 8 decks, so the appropriate estimation on pricing can be determined.

The CRM specification tool indicated that with 8 stops, required headroom needed for the SLD is about 4,5m, and required pit room is about 1,5 m and the shaft size is roughly (width) 2,5m x (depth) 2,7 m x (height) 26 m. This is with the deck-to-deck distance (from the floor level of the deck to the next deck's floor level) is about 3,0 m. In the theoretical specification used as an example, the deck-to-deck distance is the same for all decks, excluding the headroom and pit. Also, there are no fire certified doors included in the standard configuration. As the door measures are standard, the doors can be ordered without engineering by listing inputting orders specification in the purchase order, which will be posted to the supplier. With ERP system development there has been a good possibility to order the door as standard earlier, assuming that there are no protection tapes, and such included in the order.

The signalization devices are determined to be certain types, and these cannot change between different SLD’s built with the standard specification. Most of the signalization devices can be ordered with dedicated order forms and these can be as standard models. This

is the case with hall lanterns and landing call devices, assuming that there are not modifications needed between ships. For example, if access control devices are required, the modifications are needed for the devices and these need to be considered as heavy variations. Material price differences and engineering requirements need to be checked and invoiced accordingly. Support for calculating the difference can be asked from tender engineering. As the requirement is that there are no changes in the specification and the price will not fluctuate, and there isn't a need for variation engineering calculation. Thus, variation engineering can be excluded from the standard specification.

In other signalization, COP's cannot be standardized completely, but a semi-standard solution can be taken into use. This enables the production to utilize standard back boxes and other components. The COP faceplates will always have variations as the printed individual equipment number changes on every lifting device and the served decks can vary.

The software that is included in the standard lifting device is determined to be the standard version, which is used as the base for all the non-standard versions. It includes certain features by default, and they are mentioned and described in operation description. An example of the pre-installed feature is automatic parking on stormy weather, which has been mentioned earlier also. The software changes according to the slightest change on the operational description. The operational description describes the functionality of the lifting devices with their additional functions. It is common for shipyards and shipowners to ask modifications to the operational description and cause additional engineering on possibly multiple departments. As long as the operational description is sold as a standard and there are no modifications the software can be considered as standard including the already existing features, so there will be no additional expenses. All changes in the description need to be indicated that they will cause price variation.

As the cabin dimensions are fixed to be standard and the decoration or material placement will not change in between the standard SLD orders, there is an opportunity to copy previous drawings with minor changes to the configured model. The required changes are updating the equipment numbers and order references, so they match the cabin that will be on production and is required. The BOM engineering needs to take please at the cabin factory, and hence not all engineering can be removed from the order. Nevertheless, the pure cabin engineering hours will be significantly reduced from almost 18 hours to 2 hours per cabin, assuming that useable 3D-models exist already and no other changes than the ones

mentioned are needed. If the 3D-models have to be created, the design takes about 4 hours of engineering.

7.2 Decorative specification

The decorative specification is quite simplistic in the design. The cabin has to have low costing but quality standards fulfilling and acceptable materials. The requirement fulfilling materials are mostly made from stainless steel. Similarly, the landing doors and signalization devices are kept by having low price, but an acceptable quality on the solution offered. The decorations can be very plain and simple due to these being used by the crew. These lifting devices are not meant for the paying customer, so it is not important to focus on the decorative options, but on the functionality and reliability of these. Hence, stainless steel is a good option for the overall visible materials to the end user.

The durability of the landing device needs to be kept in mind for these lifting devices, especially for the visible components for the end user. As these are the type of lifting devices that are often used to move small cargo and bigger tools in addition to crew, it is not uncommon for a pallet or such to hit the landing doors of the operating panels so that they are damaged and may cause the device to malfunction. As in these types of cases the devices need maintenance and switching components, it is a good idea to have the most commonly broken and needed components on board as spare parts. These are rarely included on the original offer or tender and should be always considered as additional sales for the delivery project. If these spare parts are sold with the ship, they can be delivered at the same time as the originally installed doors. This factor is assuming that they will not get lost in the middle of construction.

As the cruise market is concentrated in North America and EU areas, the local guidelines and certificates need to be considered. One major factor is the United States Public Health Standard (USHP) requirements. There are certain limitations on the materials in the cabins, as only one type of floor and roof that are accepted by the standard. The material cost for the USPH cabins and entire lifting device are a little higher to the one without the requirement, and it needs to be accounted for in order to fulfil the standard requirement. The only factor

affected by this is the cabin design, which needs to have some changes in the chosen materials.

As there is a high likelihood that USPH requirement will be needed also in the smaller vessels, two separate specification are created – one that fulfils the standard and another that does not. The change will only have an impact on the cabin floor, roof, and some decorations such as handrails. Nevertheless, both still fulfil the other necessary standard such as EN81-20, EN81-50, and ISO 8383 so that these are safe to operate on board (KONE, 2015; Otis, 2023).

7.3 Ordering process with standard products

There are some limitations and aspects that are required still before the standard materials can be ordered in the Marine unit as close to the MTO product as possible. One obstacle is that the standard specification needs to be transformed from the rough specification into the technical drawings that can be used time and time again. These need to be indicated so that they can be found. In the company Product Data Management System (PDM) there are general drawings available for all devices, but similarly as there are certain folders for certain projects there would need to be a folder for the technical drawings. While ordering materials, the folder needs to be indicated with great importance to prevent miss-understandings and extra engineering hours and costs. This folder should be marine specific and have also the documents needed for customer approval and class approval available. During a project where a standard SLD would be the sold product, the project folder should have links to the correct drawings that need to be copied, in order to have them easily available at correct timing.

This global drawing library should contain all needed M-drawings that need to be submitted to the customer. Also, the library should have many other devices already existing and should be kept up-to-date simultaneously as the products in general are updated by the product owners. The global drawing library should contain all the devices that are available in the offering and require M-drawings in customer documentation. The drawings can be reused in other projects as well just by changing the title block information, as equipment

numbers and customer information need to be visible in the title block. This takes minimal work hours and can be subcontracted to the cheapest possible engineering division.

However, in order to have the global M-drawing library and have added value from copied drawings, the drawing library needs to have a person in charge as a product owner. The product owner needs to be in charge of the library content. Also, the product owner needs to regularly be in contact with R&D department and follow the device availability, their obsolesce and retirements as well as the drawing library content being up to date on any given moment.

As the products are ordered, it is vital to underline that the products are ordered as standard products. This is very important to mention to listing department and engineering department in order to have the products go with standard production instead of custom designing a product that already exists. Also, the unnecessary custom engineering raises the issue that there might be special solutions put in place that require the sub-suppliers to adjust their processes, which results in additional costs. In order to have production in the standard pipeline, it is also essential to have the supply manager involved in the further ordering after releasing the order to listing engineering and design engineering to ensure the standard product features. Engineering department needs to be instructed if any engineering is needed to contact the supply manager with any clarification – big or small.

As the projects that the standard SLD could be implemented are considered as small projects, containing only one to five lifting devices in total, it is highly likely that no more than three are for service use. Furthermore, it is worth to investigating the amount of deliveries that can be reduced for the lifting device. With Marine projects, it is not uncommon to have between six and eight delivery groups with partial deliveries to the shipyard. As the delivery is not as complex as with bigger specially designed cruise ships and the number of decks is likely close to eight instead of 18 it is highly likely that the deliveries can be combined. Nevertheless, there is no possibility to pinpoint a certain amount of partial deliveries since there are variation between the shipyards. Also, as the company’s strategy is to operate in a LEAN manner, JIT deliveries are an essential part of the strategy implementation. Still, the reduction of partial deliveries should be taken into consideration when making project plan and having conversations with the customer.

As some engineering is made obsolete with the standard specification, the order process will also be faster than in full ETO projects. In full ETO projects, all components that need engineering are directed to the appropriate engineering departments. Schedule-wise, there are four weeks reserved to finish the design and have all the delivery group material ready for ordering. This four-week period is not usually actually required, and so it helps to mitigate engineering workload peaks if at hand. Additionally, if no engineering is needed then the order can be carried out to the supplier four weeks faster, only needing the appropriate time for listing the product.

The four-week reduction in the supply chain makes a single order faster, but it does not influence the project duration on full chain level nor in SL. The contract signed by the case company representatives and customer has requirements stating that when the design regarding layout, M-drawings and electrification drawings need to be submitted. Documentation that is required is needed in the early phases of the process and in that time the project needs to be already active. The material orders can be placed later with shortened buffers with lead time in the process during the project, but it does not make the project shorter all in all. The installation schedule is determined by the shipyard by publishing the block schedule to subcontractors, which serves as the base for the internal material ordering. Subcontracting companies have little to no effect on the block plan schedule, as the shipyard creates the block plan as a general guideline of their production plan. Thus, the lead time reduction effects do not show as too relevant, and it is impossible to reduce the project duration.

The block plan also defines when certain materials are needed and can be installed. As the company operated with JIT principle, the reduction of delivery groups needs to be monitored case-by-case. The overall attempt is to have as little delivery groups as possible, but this is mostly related to the actual material requirements at site. It is always a compromise of having the delivery just in time for the assembly and cutting logistics costs by concentrating the deliveries in bigger groups, accounting for the available temporary warehousing facilities available.

7.4 Class approval and required customer documentation

As ships apply for classification society's approval for safe operations, the equipment installed on board will be to fulfil the class requirement. This is why the approval for instance the case company must apply for a similar approval for all of the operational lifting devices on board. In order to get the approval for case company products, there must be certain documents that need to be submitted to the class for inspection. The class reviews these documents and grants an approval for the lifting device design. After this, a part of the commissioning is the class review on the ship in person. In the commissioning the lifting device is inspected, and it will be ensured that the lifting device is accordance with the drawings and it gets an approval from the class, that the SLD or PLD fulfils all the necessary requirements and rules.

The documents that are required depend on the classification society, but generally technical illustration drawings and material certification documents are required. In addition to the documents needed for class approval, there are several documents that the shipyard often requests. These are additional quality documents such as delivery group plans and internal inspection documents filled by engineering to prove that the cabins for instance are in accordance with the drawings.

In appendix 3 there is a list of documents that are submitted to the customer. Although documentation requirements have small variances between each other, all the documents presented in the appendix 3 are required from the case company. From the list it is visible that a lot of technical documentation is needed and these need to represent the reality of the built ship. One feature to note is that if the ships are in the same series, it is possible to apply for the approval at the same time for both ship's technical documentation. This requires that the ships are identical and have no changes in between. The layout drawings, electrification drawing, and signalization drawings need to be the same. If anything minor changes, the class requires a detailed list of variations between the solution at the first and second ship, so they are obvious. As the class approvals are applied in most cases individually, there is not much difference if there is USPH requirement or not in the lifting devices as long as the rules are obeyed and followed. In addition to the appendix 3 documents, operational description is most often required from the customer. This contains the standard features

such as the automatic parking in case of heavy weather and extreme pitching of the ships, fire detection mode and internal phone unit operation function description.

8 Challenges of the standard specification

One of the major findings that was made in the Marine internal meetings was that not all the of engineering can be excluded from projects, and so the design phase cannot be excluded. There are changing features that cannot be predicted and standardized. Some of these features are related to changes in the number of decks that the lifting device needs to serve in ships and custom-built shafts that have been built by the shipyard with variance. Also, the deck heights vary with different ships, due to lack of standardization in the global shipbuilding industry. The ship electrification and signalization require engineering. This is because the COPs for instance have variable features that have to be linked to ship reception or to the bridge, and the shipyard provided interphases vary from ship to ship. In addition, the initial electrical voltage running throughout the ship can vary. As the voltage changes, the transformer type also changes, although transformers are used in all the cases to stabilize the input current. In this section of the thesis, there are some reasons why the standardization is not feasible, among other reasons at the moment.

8.1 Specifications points that cannot be standardized

All lifting devices are drawn to precisely fit the measurements from the shaft. In the standard specification created the deck-to-deck distance, pit depth and headroom requirements have been defined accurately, the fact that distances would match this in a real live project is highly unlikely. From the same projects that were included in the cost analysis, the distances between decks have been monitored, and the differences have been listed on appendix 4. The numbers have been calculated from the core specification. They have been adjusted so that the pit depth is not taken into consideration. The distances are subtracted from the previous height measure from the next to get the distances between decks. This distance is measured from the height of the top of the deck floor compared to the measuring point defined in the layouts. The first served deck height difference marked as 1-2 in the appendix 4 table. The height is always the floor level of the first deck landing door to the second deck floor. All the lifting devices do not cover the entire decks and distances presented in the table. For example, in ship A one lifting device serves decks trough 2 to 6 and other that

serves from 6 to 12. These lifting devices serve only one deck that is the same, but still serve 4 landings and 6 landings in total.

In Appendix 4, the table there are also sister projects that have the same measurements. There are a maximum number of two direct sister ships in the data, although this feature was not limited in the data collection process. Ships F and G, as well as ships X and Y are classified as sister ships. In addition, there are projects that have many significant similarities and only a small number of changes. These all are built on the same shipyard and almost all have the same amount of devices per project. The projects cannot be directly called sister ships', but these can be put into the same category. The ships belonging to this group are the ships labelled H, K, L, P, R and S.

Table 6. The averages and standard deviations of the deck-to-deck distances in analysis

Decks	Average of the distances (mm)	Standard deviation from the distances calculated (mm)	Number of deck heights
12-13	3200,0	800,0	2
11-12	3566,7	419,0	3
10-11	3237,5	412,9	4
9-10	2935,7	306,1	14
8-9	3053,1	260,5	17
7-8	2955,0	285,9	20
6-7	3122,8	413,4	23
5-6	2901,0	325,8	25
4-5	3168,0	786,8	25
3-4	3164,0	577,3	25
2-3	3274,6	613,8	25
1-2	2902,0	448,0	25
0-1	3280,0	497,8	25

From the deck-to-deck distances, averages and standard deviations have been calculated and collected in table 6. From the results presented, the deck-to-deck height averages vary from 2441,7 mm to 3350,0 mm. Also, the standard deviation for these is higher the tolerances indicated in layouts and guided in engineering, as the smallest deviation distance is 260 mm. The guidelines vary somewhat between projects and class, but the deviation cannot be as high as is presented. The allowed fluctuation in the measurements is included in layout/GA drawings.

As the standard deviation is on a vastly different range to the tolerances, the deck-to-deck distance cannot be fitted to the standard measurement and be standardized. The variation of height affects the guide rail and cabling lengths that need to be ordered and the amount and placement of the brackets needed. Additionally, the brackets need to be on the correct spot in order to provide the needed structural support to ensure the safety of the lifting device.

In addition to the heights varying between decks, there is a significant challenge related to the lengths that need to be known in the process. The ship blocks usually cover multiple decks instead of a single block. Installing for instance the guide rails that belong in the middle of the shaft needs to cover the distance by a strict margin before fish plates are added to continue the guide rail seams along the shaft. In addition, the placement of the brackets cannot be automated since these need to be in appropriate positions to ensure structural integrity. As there is no way of predicting the place where the block seams align, predicting the measurements is next to impossible. This causes the layouts needing to be designed individually for every ship.

As the GA needs to be tailored for each ship individually, some features can benefit from the standard specification and reduce the amount of engineering work needed for the layouts. As the shaft width and depth are already defined, only the height needs to be adjusted for the GA's. In addition, the landing view drawing can have a solid base where the adjustments are easy to make as the cabin dimensions are standard, and signalization device series is already known. With this information, there can already be a general draft that can be utilized when making the base for the GA drawings. Possible reduction in layout engineering hours arise from a reduced number of needed clarifications, as the specification is locked from the shipowner and shipyard side and cannot be changed without additional variation.

Along with creating individual layouts per ship, it is highly likely that there is a need for mechanical engineering. This is because the brackets used in Layouts need to be designed in advance before ordering. Layout can try to minimize the need for engineering by using already existing bracket design, but most often additional engineering is needed. This makes it impossible to eliminate external mechanical engineering along with other engineering.

Electrical design also has some difficulties in the standardization process. The problems are not technical as there are limited matters that change, but the problem is more related to ERP systems technical requirements and labour-intensive implementation process. As the Marine

unit has 70 plus employees in a 60 000-employee company and the revenue is a very small part of the overall production, there are very limited resources and interest to develop the process on the Marine processes in the company. This has resulted in the electrification package to be not defended as a variant of the main product. It has been said to be not profitable for the company, as the savings gained from standardization do not outweigh the costs of defining this. Also, as the materials included in the electrification package will fluctuate depending on the operation requirements, it is seen as not profitable and not worth the effort of the standard electrification package creation.

There are still some features that can change in the electrification design between different ships. One of these is the initial voltage running along the ship wiring, as presented earlier. The voltage can be 400 volts or 600 volts in a particular ship. This affects the transformer type that is needed for the ship. In layouts, the locations for signalization devices are pointed out according to possible positions avoiding structural steel reinforcements beans and other obstacles that prevent making cut-outs. Similarly, electrical control panel positions are determined in layouts. This impacts the cable lengths that are needed between the devices. As far as LEAN thinking goes, it is better not to adjust the lengths locally, so the cables need to be appropriate lengths in the first place. These are small aspects that can be semi-standardized using differing listing forms and ordering the correct materials that way, but the specification would still need to be checked.

The ERP technical part is the actual obstacle in the standardization process, as electrification packages are not productized. If the electrification package would be defined and would be completely standardized, there would be a high risk of the company's internal electrification factory stacking the material on inventory. With this possible inventory, they would have better opportunities to satisfy demand. As Marine certified materials are significantly more expensive than the ones used in other departments, the inventory value can easily climb up as the demand is not stable there for all components. Also, as the Marine business is project business, the demand can fluctuate which drives the required safety stock value very high. This can result in obsolete materials and waste.

Even if the electrification packages would be productized, and they would not be MTS materials, the variations in projects can make the standard electrification packages obsolete. With these factors in mind, the labour-intensive process of standardizing electrification packages is seen as not profitable in the company. Hence, electrification engineering will

not be standardized and cannot be assumed as order-ready packages. Additionally, for lack of productizing, electrification is often delivered in projects in three to four separate deliveries. This would mean that the electrification packages would need to be only sections from the entire electrification, which makes the up keeping of the packages more demanding and labour-intensive. This is an argument also against productizing the electrical packages and a difficulty in the entire standard SLD project.

Furthermore, the lack of standardization in electrification makes it mandatory for electrification engineers to pick out individual components into lists that are needed for certain configurations and create component orders instead of ordering standard electrification packages. There are attempts to build a component tree structure to make listing and BOM-engineering easier and faster, cutting the costs further. But as the development is ongoing at the moment, and it is out of the scope of the thesis, the current outcome is that electrification engineering cannot be standardized at the moment.

The classification society and the customer require certain documentation from electrification engineering mentioned in Appendix 3. Designing and updating these per project requires engineering and clarifications. Furthermore, in Marine electrification engineers are in close contact with FL also representing signalization. This specific documentation is created and orchestrated by the chief electrification engineer, which makes the standardization difficult. With all these obstacles in the standardization process, the reduction in electrical engineering can be quite minimal if any is possible at the moment.

In addition to the electrical wiring and connections within the lifting device shaft and cabin, the COP cannot be completely standardized either. This is because the COP has to have correct deck call buttons, function buttons and must fulfil all requirements given by the class. Also, every lifting device has its own individual equipment number that is engraved or laser printed on the COP faceplate. This is to make the device identification easier in later maintenance operations and with device modernization projects. There is an existing semi-standard model that can be used in the production to drive down the costs allocated to the lift. There are certain specification requirements that need to be fulfilled with measurements and product materials, if the semi-standard model requirements are fulfilled. Instead of signalization engineers drawing at least 17 technical documents internally for manufacturing, the signalization engineer has to only make half of the technical drawings. This makes it possible to reduce engineering hours quite significantly. The semi-standard

design can include access control systems, but it doesn’t take into account the other engineering department's work that is then needed in order to have the access control device working fully. The semi-standard design reduces the needed signalization design hours from 7 hours to 4 hours per lifting device. COP BOM cannot have a similar reduction as the electrification factory internal listing operations still need to take place, in order to have correct materials at the assembly.

If the semi-standard COP solution is as close as a complete copy of a previous semi-standard COP, the design work can be reduced even more. The only load plate information, and COP buttons arrangement drawings need to be updated for each project. This is only feasible if no access control systems are accounted for. If the COP does not have other changes in load plate information and button configuration, the design hours can be reduced from 4 to 2 hours.

Additional access control systems cannot be included in the standard specification either since these impact multiple engineering departments processes. These control systems are commonly implemented with a type of card reader or a number combination lock. If these are implemented, heavy signalization, electrical and software engineering is required to accomplish the access control. The access control systems are common within SLD’s since these are meant for the crew and the owner often want to prevent the accidental customer access to the crew facilities on ships. These need to be included in the operational description and require collaboration of the project manager and the chief design engineers, and add costs for the project. The operation description does not have to be done from scratch for each project, as previous documents can be used as a base for new documents.

Materials needed for the lifting device need to be identified and listed in the ERP system, so engineering departments know what is needed for which delivery group and to ensure that all needed materials are ordered. This is in the hands of the listing department, who prepare ERP system activities for engineering, which allow the engineering to invoice the project with their work. As the material fluctuates and the integration between CRM specification tool and ERP system is now working so reliably, the specification could be used for ordering, as listing engineering cannot be excluded from projects. The listing work can be reduced slightly as the premises are set up so that the specification is clear and will not change during the projects. If for some reason there will be updates in the specification, listing engineering work needs to be included to the variation price and invoiced accordingly.

Supply management in projects is also an aspect that cannot be standardized. Supply management has been described as project management in the supply line. Without managing projects, one of the major project success factors is lost. The amount of engineering needed for supply management can be reduced if the number of partial deliveries is reduced with FL, and the specification is locked in an early stage of the project. Furthermore, as the specification is closer to a standard specification and the changing variables are reduced, the need for quality gates currently needs to be rechecked. Internal quality gates such as design quality review might not bring the desired value as they do in projects with more variations. The need for every individual quality gate needs to be observed in light ETO projects individually based on possible variations that are purchased by the shipyard. Added costs from using engineering services needs to be taken into account in variation invoices. This cuts down the need for change management and so-called firefighting work.

8.1 Defining cost for the SLD's trough CRM

The cost per lifting device is best to be calculated with the CRM based specification and pricing tool used within the company. The main reason for this is that the material pricing is maintained globally and is frequently updated with the latest indexation. With this the material prices are updated and are more in line with the global trends and so the risk of pricing the lifting device too low is significantly lower. This makes the pricing more reliable. Also engineering price updates, that are updated annually, are maintained and shown in the CRM tool.

The CRM tool calculates the material prices according to the input from the specification creator choices and considers the estimate on the engineering hours required for a certain project. The tool calculates the price with a certain pre-given hourly rate. The number of hours needed can be manually adjusted in the system. It is highly recommended and even commented on the CRM tool that the hour estimation needs to be cross-checked with supply and engineering teams and departments before submitting the offer. The simpler and the less overall engineering the project needs, the less costs will be generated for the project.

The lifting device installation is priced with a separate pricing tool that needs to be added to the total price with FL mark-up. The installation price is very much dependent on the lifting device specifications and reflects the number of decks the device serves, for instance if the lifting device is a model 1 or a model 2 device. After installation, the commissioning also requires work hours that need to be calculated in the tender. Commissioning accounts for the final adjustments on the brakes and doors, for example, so the lifting device has a safe and comfortable ride throughout. A typical lifting device installation will take about 600-700 h of installation work and 160h of commissioning. From the hourly rate, the installation price can be calculated.

8.2 Cost impact on the product and refused engineering

As established, the engineering cannot be fully disregarded and ordering process strategy cannot be changed to full MTO. Nevertheless, there are many functions that can be standardized, and some reductions can be done in the engineering hours. This method of ordering materials can be called as light-ETO orders as the process is still ETO but has some MTO features and semi-finished products. All of these cost savings come with many requirements, and they are not available in the first light-ETO project. The reason for this is that the standard specification and drawings will need to be created in the first place before they can be used as copy references. After the design is validated and can be used to copy in future projects, full cost savings can be achieved. Still, it needs to be noted that the reduction is based on several heavy assumptions, which most importantly lean on the fact that there are no changes and standard solution has once been created and used in upcoming projects.

In table 7 the reduction calculation with engineering hours is presented. The table 7 summarizes the engineering hours that have been used for projects, and how the project hours distributed between the engineering departments by category. The engineering conducted internally in the Marine unit will be reduced by 37,2 percent and external engineering by 62,6 percent from total. The analysis presents that on average in closed small projects 274,7 hours have been spent on design, pricing, and supply for a single lifting device (PLD and SLD). By standardizing and implementing the light-ETO model, the engineering hours can be reduced by 48,7 percent. This would mean that as on the project level

engineering costs represent 10-20 percent of full chain costs, there is 4,8 to 9,6 percent cost reduction. Further breakdown of the engineering reduction is listed in table 7.

Table 7. Reduction on engineering hours per engineering category.

Engineering category	Actual work on ERP system	% Of total actual work	Actual work per lifting device	% Of reduction to planned work in Standard SLD	Planned work per Standard SLD
External engineering					
Cabin	2274,5	13,4 %	36,1	-77,4 %	8,2
Door	266,5	1,6 %	4,2	-100,0 %	0,0
Electrification Hardware	1193,8	7,0 %	18,9	-9,6 %	17,1
Machinery	252,5	1,5 %	4,0	-100,0 %	0,0
Mechanics	683	4,0 %	10,8	-5,5 %	10,2
Landing Signalization	516,3	3,0 %	8,2	-75,6 %	2,0
Signalization - COP	757,2	4,4 %	12,0	-37,8 %	7,5
Software	1521,4	8,9 %	24,1	-100,0 %	0,0
Total external engineering	7465,2	43,8 %	118,5	-62,0 %	45,0
Marine internal engineering					
Supply Management	3784,5	22,2 %	60,1	-40,0 %	36,0
Listing	740,5	4,3 %	11,8	-10,0 %	10,6
Chief Electrification	1849	10,9 %	29,3	-35,6 %	18,9
Layout /General Arrangement	2838,5	16,7 %	45,1	-34,0 %	29,7
Variation tendering	351	2,1 %	5,6	-100,0 %	0,0
Total Marine internal engineering	9563,5	56 %	151,8	-37,2 %	95,3
Grand Total	17029	100,0 %	270,3	-48,1 %	140,3

8.2.1 Variating materials on different order forms

As presented in previous chapters, a partly standardized specification is possible and can be created as the case company product. However, there are strict limitations to the specification that need to be considered in the project management and sales. In order to keep the price as it is with the standard specification, the variation cannot be considered. If there are changes in the specification, they need to be purchased by the customer separately. Furthermore, in every case that variations are sold, the variation impacts need to be checked with all the key departments such as engineering, supply team and factories.

Some features in the lifting devices are more commonly changed than others. As these features, like fire class approved doors and access control system implementations, are required and there is a strong temptation to use an already calculated variation as a base for the variation price. Nevertheless, it is better to check the variation pricing with the category engineers, and tender engineers to see the real impact on the price. This is to ensure all appropriate indexations and the correct hourly rates are used in calculations and the changing engineering requirements are considered. After the appropriate units affected have been consulted on the matter, the risk of incorrect pricing in variations becomes non-existent. The price needs to be tied up to certain strict deadlines to ensure that the needed time for engineering is granted, and the materials are not in production with suppliers on too early phases.

It is valuable to note that not all changes require huge engineering changes, and this can be taken into account in making the model. For instance, a change in COP location from on B side wall to D-side does not have an impact on other department configurations than cabin design. This can be modified to an existing model with relatively small number of hours, as the standard cabin PDM structure is copied and not modified significantly. This is considering the variation is sold in advance before engineering has started for the production.

On the other hand, an example of a bigger variation can be changes in operational description, as the changes most likely will impact signalization, electrification, and software design in addition to materials. This matter depends on the broadness and scope of the change and has to be checked case by case. This fact highlights the need for a visible deadline for variations that needs to be included in the contracts and needs to be informed clearly to the customer.

9 Conclusion and discussion

The research shows that the marine environment and shipbuilding processes are highly complex and variable features arise from different stakeholders during the execution phase. This is valid for both in design and material delivery phases. Shipbuilding can be construed as heavy ETO with little to no room for standardization on a larger scale. As the ship construction contains multiple features that have causalities and significant effects between each other, flexibility in engineering is required from all stakeholders, material producers and subcontractors involved.

Keeping in mind the limitations, the offerings can have some features of the lifting devices standardized. Implementing the standard solution requires flexibility from shipyards as the standard solution raises requirements, for instance the shaft dimensions, cabin dimensions and the signalization device types are limited to pre-defined measures by the case company. Furthermore, this requires that the shaft dimensions are considered while making the design for the entire ship and its interior dimensions. In the sales phase, the limitations need to be highlighted to the customer.

In the customer contract preparation, it is important to avoid misunderstandings and have all matters such as scope and responsibilities aligned. In addition, the reference for the new ship needs to be only tied to the light ETO specification or to a ship built with only the light ETO lifting devices. This is since some other ships have special solutions that might not be feasible or require extensive amount of engineering in order to implement the solution on board. This needs to be avoided since the extensive engineering removes the benefits of the light ETO device. Clear communication about the specification details can reduce misunderstandings and avoid feasibility issues during projects. These feasibility issues can cost the projects significantly if discovered only in the execution phase and an alternative solution needs to be offered to the customer, although other solutions should be in the original contract. Also, this helps to avoid unforeseen costs that can impact heavily smaller projects' profit margins.

As the specification is frozen from the beginning of the project and the project is sold using the light-ETO standard products, any changes that might occur after the project has started will need to be invoiced from the customer. This needs to be indicated in the contract side

as well. The number of revision rounds needs to be limited to one that is included in the offer. All additional changes that are proposed from the shipyard need to be invoiced separately as variations. The invoicing needs to take into account all the units that the change is affecting. This has been previously highlighted with an example of adjusting the operational description changes.

If all these criteria are met in the projects, operational functions can achieve 4,78 percent cost savings. This does not take into account the FL mark-up that needs to be added to the sales price. SL mark-up is included in the CRM specification and pricing tool. FL mark-up can give a little negotiating room for sales and a buffer for unexpected costs that may arise.

With the light-ETO projects, it needs to be taken into account that many of the cost savings are based on the premise that the design is ready. As the required specification is not yet available, it has to be created once on the first light-ETO standard project. There is a high likelihood that the project will have overshooting costs if sold with the standard pricing. This needs to be accounted for while reviewing the feasibility and first implementation process. With the light-ETO specification it is important to record lessons learned from the first project, as there is a high risk of coping with similar mistakes in following projects.

As concluded, the engineering can be reduced in the projects and the order lead time can be reduced. This affects only the material orders, where non-engineered materials are included. This does not affect the project total duration, as this is highly dependent on the shipyard schedule. The orders need to be opened already to the company ERP systems in advance. This means that the project needs to be open in FL side as well as in SL, in order to have layout engineering and electrical engineering conducted for the approvals. The amount of deliveries and their schedules have to be checked case-by-case, as different shipyards have slightly altered working methods and block plan and schedule affects this significantly.

9.1 Potential points to investigate more after this thesis

There are several potential points of interest that could be reasonable to investigate. Further automations of the CRM pricing tool and ERP system integration and feasibility would be beneficial to investigate. If the specification that is brought from the CRM tool to ERP system could be used in listing, this could reduce listing engineering hours and bring costs

savings. Additional functionality for delivery group pricing could be seen as beneficial, if the prices could be better based on the CRM tool pricing. This would help to give more accurate prices for deliveries, and for instance partial customs clarifications could have support from this. Similarly, BOM engineering standardization and effects to the production would be good to investigate further. The external engineering departments are having their own development actions ongoing and utilizing their results can help drive overall costs down slightly in projects.

Furthermore, the interviews with Marine personnel revealed that, in the CRM pricing and specification tool has the ability to create certain limitations on the specification choices. This limitation creation was called sequencing, and it could be implemented to the environment in order to limit the possible variations, so that only small changes could be applied to the specification on the sales. This would direct the specification automatically in the direction of using standard process materials and enable better cost control in projects. For this, further investigation needs to take place to see all the different device prices and the impacts on the various engineering departments.

A major point of interest to do a study on would be surveying more in detail the possibilities to influence the ship overall design, such are deck distances. Also, it would be beneficial to analyse the customer response when proposed to use the light-ETO specification in the project. The customer response to the variation policy should also be included, as it plays a significant role in the standard specification and especially keeping the specification standard throughout the process.

Additionally, it would be good to make a standard model of a passenger lifting device so projects with 5 or more lifting devices could be used in the standard offering. This could even be applied to PLD’s with changing interiors if the interior is purchased locally and installed by a subcontractor locally. It is also worth researching if engineering can be outsourced and conducted in India for example for lower hourly cost, which would result in cost savings. This leans on the assumption that the outsourced engineering savings are greater than managing the subcontracted engineering department.

As the development with electrification productizing is ongoing, its effects to the standard offering and it’s pricing need to be monitored while available. As the development is

ongoing at the time of writing, the effects could not be included in the light-ETO model in this piece of research.

Thinking about the future, it is also beneficial to consider future trends and their effect on the industry in general. For example, the fourth industrial revolution is gaining ground and in supply chain management LEAN, Agile, Resilient and Green (LARG) is starting to have visibility in the industry according to a 2019 study (Ramirez-Peña et al.). The study found that green values are more in demand than expected. Additionally, the study found that there are variances between technological integrations, where for instance Meyer Werf stands out in their technological innovations (Ramirez-Peña et al., 2019). It is worth to investigating if these features have an impact on the company in general and the product offering, such as the light-ETO SLD. At the same time, as green values come into play more and more, do some features need to be changed from the determined specification in order to increase energy efficiency to keep up with the megatrend and competition.

References

APEC. 2010. Standardization: Fundamentals, Impact, and Business Strategy. Asia Pacific Economic Cooperation (Organization). Vol 3.

Atan Z., Ahmadi T., Stegehuis C., Kok T. & Adan I. 2017. Assemble-to-order systems: A review. European Journal of Operational research. Vol 261, pp. 866-878.

Bamber G.J., Stanton P., Bartram T. & Ballardie R. 2014. Human resource management, LEAN processes and outcomes for employees: towards a research agenda. The International Journal of Human resource management. Vol 25. No.21, pp. 2881-2891.

Bruce G. 2021. Shipbuilding Management. 1st edition. Singapore: Springer

Chantier De L'Atlantique. 2022. Modernization and Valorization of the Ship. [Webpage]. [Cited 14.10.2022]. Available: https://chantiers-atlantique.com/en/our-activities/services/valorization-of-the-ship/

Chokshi N. & Payne C. 2020. How giant ships are built. New York Times. 17.6.2020. [Web-article]. [Cited 6.1.2023]. Availbe: https://www.nytimes.com/interactive/2020/06/17/business/economy/how-container-ships-are-built.html

Ciccoi P., Madolini M., Nardelli M, Raffaeli R. Design Optimization: Tools and Methods for ETO Products. Design Tools and Methods in Industrial Engineering, 2019, pp.516-527

DNV. 2022. Certification of materials and components. [Webpage]. [Cited 24.10.2022]. Available: https://www.dnv.com/maritime/certification-materials-components.html

El-Khalil R., Leffakis Z. M., Hong P. C. 2019. Impact of improvement tools on standardization and stability goal practices, An empirical examination of US automotive firms. Journal of Manufacturing Technology Management Vol. 31 No. 4, 2020 pp. 705-723

Esteve-Perez J. & Garcia-Sanchez A. 2015. Cruise market: Stakeholders and the role of ports and tourist hinterlands. Maritime Economics & Logistics Vol. 17, 3, pp. 371–388

European commission. 2022. Shipbuilding sector. [Webpage]. [Cited 14.10.2022]. Available: https://single-market-economy.ec.europa.eu/sectors/maritime-industries/shipbuilding-sector_en

Fullerton R.R. & McWatters C.S. 2001. The production performance benefits from JIT implementation. Journal of Operations Management. Vol.19. pp.81–96

Gao S. & Low S.P. 2014. LEAN Construction Management – The Toyota Way. Springer. Singapore.

Gosling J. & Naim M. M. 2009. Engineer-to-order supply chain management: A literature review and research agenda. International Journal of Production Economics 122, pp. 741-754

Hayes, R. H., & Wheelwright, S. C. (1979). Link manufacturing processes and product life-cycles. Harvard Business Review, 57(1), pp.133–140.

IACS 1. 2022. International association classification societies. Members. [viewed 8.6.2022] Available: https://iacs.org.uk/about/members/

IACS 2. 2022. International association classification societies. About IACS. [Website]. [Cited 8.6.2022]. Available: https://iacs.org.uk/about/

IMO 1. 2022. Brief History of IMO [Webpage]. [Cited 24.10.2022]. Available: https://www.imo.org/en/About/HistoryOfIMO/Pages/Default.aspx

IMO 2. 2022. Introduction to IMO. [Webpage]. [Cited 24.10.2022]. Available: https://www.imo.org/en/About/Pages/Default.aspx

IMO 3. 2022. SOLAS. [Webpage]. [Cited 24.10.2022]. Available: https://www.imo.org/en/KnowledgeCentre/ConferencesMeetings/Pages/SOLAS.aspx

IRCLASS. 2022. Marine Component Certification. [Webpage]. [Cited 21.10.2022]. Available: https://www.irclass.org/marine/ship-classification/marine-component-certification/

ISO 47.020.20. 2022. Marine engines and propulsion systems [Webpage]. [Cited 22.11.2022]. Available: https://www.iso.org/ics/47.020.20/x/

ISO 8383. 1985. Lifts on ships - specific requirements. International Organization for Standardization. Switzerland.

ISO/IEC. 2016. ISO/IEC Directives, Part 2, Principles and rules for the structure and drafting of ISO and IEC documents. International Organisation for Standardization / International Electrotechnical Commission, Vol 7.

KONE. 2015. Lift standards EN 81-20 and EN 81-50. [Web-document]. [Cited 3.1.2023]. Available: https://www.kone.co.uk/Images/KONE-Factsheet-EN81-20-50_tcm45-32332.pdf

Kuster J., Huber E., Lippmann R., Schmid A., Schneider E., Witschi U. & Wüst R. 2015. Project Management Handbook. 4th edition. Berlin. Heidelberg: Springer Berlin Heidelberg.

Lock D. 2012. Project management. 10th edition. Surrey. Gower Publishing Limited.

LR. 2022. Lloyd's Register: Marine Equipment – Certification. [Webpage]. [Cited 21.10.2022]. Available: https://www.lr.org/en/product-certification/marine-equipment-certification/

Marine Insights. 2019. What Is Advanced Outfitting in Shipbuilding? [Webpage]. [Cited 14.10.2022]. Available: https://www.marineinsight.com/naval-architecture/advanced-outfitting-in-shipbuilding/

Münstermann B. & Weitzel T. 2008. What Is Process Standardization? International Conference on Information Resources Management. CONF-IRM 2008 Proceedings 64.

Münstermann B., Eckhardt A., Weitzel T. 2010. The performance impact of business process standardization, An empirical evaluation of the recruitment process. Business Process Management Journal Vol. 16 No. 1, pp.29-56

Naidu, N. V. R., Babu, K. M., Rajendra, G. 2006. Total Quality Management. New Age International P Ltd. New Delhi.

Olhager, J. 2003. Strategic positioning of the order penetration point. International journal of production economics. Vol. 85, num. 3, pp. 319–329.

Öner-Közen M. and Minner S. 2017. Impact of priority sequencing decisions on on-time probability and expected tardiness of orders in make-to-order production systems with external due-dates. European journal of operational research, 2017, Vol.263 (2), pp.524-539

Otis. 2023. Otis Cruise Ships. [Webpage]. [Cited: 12.3.2023]. Availbe: https://www.otis.com/en/id/our-company/global-projects/cruise-ship

Pacagnella, J. A. C., Silva S. L., Pacifico O., Ignacio P.S.A., Silva A L. 2019. Critical Success Factors for Project Manufacturing Environments. Project Management Journal. Vol 50(2) pp 243-258

Port of Rotterdam. 2022. General terms and conditions including port tariffs. [Website]. [Cited 9.6.2022]. Available: https://www.portofrotterdam.com/sites/default/files/2021-12/port-tariffs-terms-conditions-2022-port-of-rotterdam.pdf

Rafiei H. & Rabbani M. 2011. Order partitioning and Order Penetration Point location in hybrid Make-To-Stock/Make-To-Order production contexts. Computers & Industrial Engineering. Vol 61. pp.550-560

Rafiei, Rabbani and Kokabi. 2014. Multi-site production planning in hybrid make-to-stock/make-to-order production environment. Journal of industrial engineering international, 2014, Vol.10 (3)

Rajagopalan S. 2022. Make to order or Make to Stock: Model and application. Management science, 2002, Vol.48 (2), pp.241-256

Ramirez-Peña M, Abad Fraga F. J., Sánchez Sotano A.J. and Batista M. 2019. Shipbuilding 4.0 Index Approaching Supply Chain. Materials, 2019-12-10, Vol.12 (24), pp.4129

Roth M. L. & LeeK. Y. Computational Ship Design, Springer Nature Singapore. Singapore.

Schank J. F., Pung H., Lee G. T., Arena M. V., Birkler J. 2005. Outsourcing and Outfitting Practices. RAND Europe. United Kingdom Ministry of Defence. [Web-document]. [Cited: 21.10.2022]. Available: https://www.rand.org/content/dam/rand/pubs/monographs/2005/RAND_MG198.pdf

Statista. 2023. Cruises – Worldwide. [Webpage]. [Cited 2.1.2023]. Available: https://www.statista.com/outlook/mmo/travel-tourism/cruises/worldwide#global-comparison

Traficom 2022, Ice Classes of a Ship. [Website]. [Cited 9.6.2022]. Available: https://www.traficom.fi/en/transport/maritime/ice-classes-ships?toggle=Finnish%20ice%20classes&toggle=Ice%20Class%20Regulations%20and%20the%20Application%20Thereof

Wang, J.; Yin, J.; Khan, R.U.; Wang, S.; Zheng, T. 2021. A Study of Inbound Logistics Mode Based on JIT Production in Cruise Ship Construction. Sustainability 2021, 13, pp. 1588.

Wei Y. 2012. Automatic generation of assembly sequence for the planning of outfitting processes in shipbuilding. Delft. VCSS. pp.223-253

Willner O., Powell D., Gerschberger M. & Schönsleben P. 2016. Exploring the archetypes of engineer-to-order: an empirical analysis. International Journal of Operations & Production Management. Vol. 36. No. 3. pp. 242-264

Yang L.R. 2011. Key practices, manufacturing capability and attainment of manufacturing goals: The perspective of project/engineer-to-order manufacturing. International Journal of Project Management. Vol 31. pp.109-125

Yang, B. & Burns, N. 2003. Implications of postponement for the supply chain. International journal of production research. Vol. 41, num. 9, pp. 2075–2090.

Zheng, Y.; Ke, J.; Wang, H. Risk Propagation of Concentralized Distribution Logistics Plan Change in Cruise Construction. Processes. Vol 9. pp.1398

Appendix 1. The key success factors in manifesting project or ETO projects. The success factors have been grouped in four categories. (Pacagnella et al. 2019)

Efficiency	Impact on the customer
Team integration (HR) Establishing clear objectives (PM) Lessons learned (PM) Use of previous technologies (TA) Time and money reserves (PM) Risk identification (PM)	Team flexibility (HR) Time and money reserves (PM) Client engagement (RS) Disincentive mechanisms (RS) Risk identification (PM)
Impact on The Team	**Preparation for the future**
Team experience (HR) Team integration (HR) Conflict handling (HR) Project management office (OF) Effective communication (OF) Analysis of critical resources (PM) Analysis of limiting factors (PM) Risk identification (PM) Risk monitoring (PM)	Project manager experience (HR) Support from top management (OF) Lessons learned (PM) Interdependence between projects (PM) Technical performance control (TA) Previous technologies (TA) Project management office (OF)

Appendix 2. Marine Supply plan Power Point: Marine process (Case Company. 2022)

Marine process
0b Order Booking
0c Order to SL
1b Layout draiwing submit
1c Layout drawing approval
2 Spesification frozen
2z Pre-delivery review
3 NRP orded released to production
3s Material arival at site
4 Start insallation
4c Insallation completed
5 Handover to customer

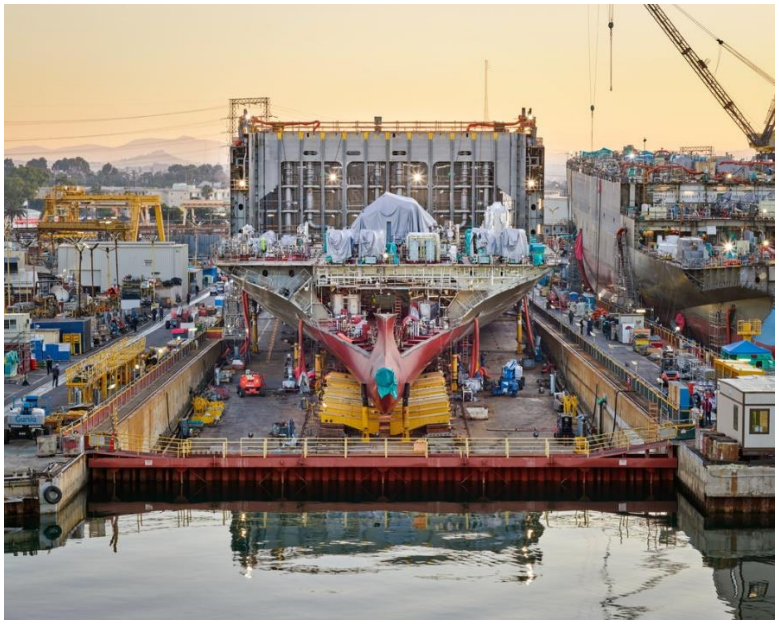
Appendix 3. An example of customer documentation on projects.

Type	Document Source	Document description
Certification	Internal PDM	Asbestos free certificate of lifting device
Certification	Material supplier	Lifting device rope certificate
Technical drawing	CDE Cabin	Lifting device cabin drawing
Technical drawing	CDE ELHW	Lifting device external cabling drawing
Technical drawing	CDE ELHW	Lifting device Intercom scheme
Technical drawing	CDE ELHW	Lifting device internal cabling drawing including transformer, control panel and main switch
Technical drawing	CDE Layout	General arrangement drawing (Landing View)
Technical drawing	CDE Layout	General arrangement drawing (stiffeners in shaft and cut-outs for door)
Technical drawing	CDE Layout	General arrangement drawing of Lifting device (Elevation)
Technical drawing	CDE Layout	General Arrangement Drawing of Lifting device (Lifting device cross section, plan of lifting device pit and headroom section)
Technical drawing	Sign engineer or CDE	Lifting device Cabin operating panel (COP)
Technical drawing	Sign engineer or CDE	Lifting device Landing signalization drawing
Quality document	SM/PM	Delivery group Plan
Quality document	CDE Layout	Factory Acceptance Inspection (FAI) Report for Lifting device
Quality document	CDE Layout/ CDE Cabin	Component Weight and CoG Data Sheets for Lifting device and doors
Quality document	CDE Layout	Lifting device forces calculations, pit, counterweight, and rope calculations
Quality document	SM/PM	Lifting device Product and functional description
Quality document	SM/PM	Painting & Surface Specification

Appendix 4. Deck to deck distances with the observed projects. Measures in millimetres.

ID	3570	5124	5392	6269	6354	6635	6944	7010	7235	7273	7435	7436	7467	7548	7638	7643	7769	7892	7909	8289	8430	8552	8729	8782	9017
Decks	Ship A	Ship B	Ship C	Ship D	Ship E	Ship F	Ship G	Ship H	Ship I	Ship J	Ship K	Ship L	Ship M	Ship N	Ship O	Ship P	Ship Q	Ship R	Ship S	Ship T	Ship U	Ship V	Ship W	Ship X	Ship Y
13-14	4000												2400												
12-13	3700												3000								4000				
11-12	3350												3000		2750						3850				
10-11	3350	2750	2800					2800		2800	2800	2800	3200	2800	2750	2800		2800	2800		3850				
9-10	3350	3300	3000					3000	2800	3000	3000	3000	2950	3100	2750	3000		3000	3000		3850			2750	2750
8-9	3200	2900	3000	3000				3000	2500	3000	3000	3000	2750	3100	2900	3000		3000	3000	3000	3850	2300		2800	2800
7-8	3200	2900	3400	3000	2700			3200	1700	3100	3400	3400	3075	2800	3200	3200	3700	3400	3400	3000	3850	2800	2800	3300	3300
6-7	3500	2900	2900	2800	2700	2600	2600	2900	3400	2600	2900	2900	2875	2900	2400	2900	3500	2900	2900	2800	3850	2600	2600	2800	2800
5-6	4200	2900	3300	2900	1900	2600	2600	2900	2900	3300	3300	3300	2950	2850	3050	2900	6300	3050	3300	2900	4300	2900	3000	2800	2800
4-5	5600	3300	3000	2900	2800	3100	3100	2900	2900	3000	3000	3000	3000	2850	3050	2900	3500	3000	3000	2900	4300	3200	2800	3000	3000
3-4	4300	2850	3500	2900	2800	2650	2650	3500	2900	3500	3500	3500	2750	3100	3200	3500	4200	3500	3500	2900	5365	2900	2800	2800	2800
2-3	2000	2900	2700	2900	2950	2600	2600	2700	3200	2700	2700	2700	3050	3200	2700	2700	3500	2700	2700	2900	4650	2800	3000	3000	3000
1-2	2800	3700	3300	2900	3050	2500	2500	3300	2900	3300	3300	3300	3700	2600	3300	3300	4200	3300	3300	3400	4650	2800	3000	3800	3800
0-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 5. Pictures from NASSCO Shipyard in the United States of a ship hull, a block and lifting a block onboard. (Chokshi & Payne, 2020)



1. Ship Hull on drydock

2. A Ship block

3. Lifting a block on board