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Order Specification Management: evaluation and path to improvement

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TIIVISTELMÄ:

Tämän päivän markkinat asettavat yrityksille jatkuvasti enemmän paineita toimittaa tuotteita ilman vikoja, lyhyemmillä toimitusajoilla ja nopeammilla suunnittelun käänteillä. Nämä vaatimukset aiheuttavat haasteita erityisesti yrityksille, joiden tuotantomuoto on tilauksesta suunnittelu. Näiden yritysten täytyy arvioida tuotteen suunnittelua, selvittää työkaluvaatimukset, viimeistellä prosessisuunnitelmat sekä toimittaa tuotteet aikataulussa. Tilauksesta suunnittelevien firmojen myynti-toimitusprosessissa on mahdollisuus hyödyntää vanhoja suunnitteluratkaisuja uusien tuotevariaatioiden luomisessa, jolloin asiakaskohtaiset suunnittelukustannukset laskevat ja läpimenoajat lyhenevät.

Order Specification Management (OSM) sovellus kehitettiin tapausyritykselle lisäämään tuottavuutta projektin hallinnassa. Sitä käytetään pääasiassa ostotilauspyyntöjen luomiseen, päivittämiseen ja poistamiseen. Tutkielman tarkoituksena on saada objektiivinen käsitys sovelluksen nykytilasta haastattelemalla sekä sovelluksen kehittäjiä, että sen käyttäjiä. Tavoitteena on saada vastaus kolmeen tutkimuskysymykseen: 1) Miten lean periaatteet, tuotekonfiguraattorit ja tuotteen elinkaaren hallinta voivat parantaa tehokkuutta tilauksesta suunnittelevien yritysten toiminnassa? 2) Mitä hyötyjä OSM sovellukselle on alun perin tavoiteltu ja mikä on sovelluksen nykytila? 3) Onko OSM tarkoitukseen sopiva kohdeyritykselle?

Teoriaosuudessa käsiteltävät aiheet ovat lean, tilauksesta suunnittelu, tuotekonfiguraattorit ja tuotteen elinkaaren hallinta. Tutkielmassa käytetty tutkimusmenetelmä on laadullinen tapaustutkimus. Tutkielman tiedonkeruussa on käytetty haastatteluja sekä kyselyä. Lisäksi kohdeyrityksen sisäisiä dokumentteja on käytetty tutkielmassa toissijaisena aineistona.

Kehittäjien kanssa tehdyissä haastatteluissa selvisi, että OSM:n kehittämisellä pyrittiin helpottamaan projekti-insinöörien työtä sekä mahdollistamaan olemassa olevan datan uudelleen käyttämistä. Tutkimuksen tulokset osoittavat, että OSM:n kehittäjillä ja käyttäjillä on eriäviä mielipiteitä sovelluksesta. Kaikki haastatellut kehittäjät olivat sitä mieltä, että OSM toimii sille tarkoitetulla tavalla, kun taas käyttäjät arvioivat sovelluksen käytettävyydessä olevan parantamisen varaa. OSM sai kritiikkiä erityisesti hitaudestaan sekä heikosta datan laadusta. Teemahaastattelun osallistujat tunnistivat kuitenkin myös positiivisia asioita OSM:stä kuten, että sen avulla näkee enemmän yksityiskohtia tuotteesta kuin SAP:ta käyttämällä. Lisäksi OSM:ää käyttämällä ei tarvitse kopioida tietoja monista eri dokumenteista ja paikoista.

KEYWORDS: Lean, Tilauksesta suunnittelu, Suunnittelun uudelleenkäyttö, Tuotteen elinkaaren hallinta, Tuotekonfiguraattori

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ABSTRACT:
The contemporary market puts continually growing pressure on firms to deliver products with no defects, brief lead times, and rapid design turns. These requirements are particularly challenging for engineer-to-order firms who must discover how to evaluate product design, find out tooling requirements, finish process designs, and deliver items on schedule. In engineer-to-order companies' sales-delivery process there is a possibility to utilize design reuse while creating new product variations which leads to decreased customer-specific design costs and shorter lead times.

Order Specification Management (OSM) was developed by the case company to increase productivity in project management. It is mainly used for creating, updating, and deleting purchase order requisitions. The purpose of this thesis is to get an objective perception of the application's current state by interviewing both developers and users. The objective is to get answers to three research questions: 1) How can lean principles, product configurators, and product lifecycle management improve efficiency in engineer-to-order companies? 2) What benefits have been sought originally by implementing OSM and what is the current state of the system? 3) Is Order Specification Management fit for purpose for case company?

Theoretical topics that are covered in this thesis include lean, engineer-to-order, product configurators, and product lifecycle management. Research method used in this thesis is qualitative case study. For data collection interviews and a questionnaire are used. In addition, the case company's internal documents are used as a secondary data.

The interviews with developers revealed that the purpose of developing OSM was to make project engineers' work easier and make it possible to reuse the existing data. The results of the study indicate that developers and users have different opinions about the application. All the interviewed developers thought that OSM is working as it is supposed to whereas the users thought that there is room for improvement in the usability of the application. OSM received criticism especially about its slowness and poor data quality. However, the participants of the focused interview recognized also positive things about OSM, such as its ability to see more details about products compared to SAP. Furthermore, when using OSM there is no need to copy data from several documents and places.

KEYWORDS: Lean, Engineer-to-order, Design reuse, Product Lifecycle Management, Product configurator

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List of abbreviations

BOM	**Bill of Materials**
ETO	**Engineer-to-order**
OSM	**Order specification management**
PLM	**Product lifecycle management**
POR	**Purchase Order Requisition**
QMS	**Quotation management system**

1 Introduction

The contemporary market puts continually growing pressure on firms to deliver products with no defects, brief lead times, and rapid design turns (Kumar & Wellbrock, 2009). These issues are particularly challenging for engineer-to-order (ETO) firms who must discover how to evaluate product design, find out tooling requirements, finish process designs, and deliver items on schedule. In engineer-to-order companies' sales-delivery process there is a great opportunity to utilize design reuse, which refers to reusing previously approved design solutions while creating new product variations in accordance with customer-specific specifications (Brière-Côté et al., 2010). By utilizing design reuse, customer-specific design costs can be cut down and lead times can be shortened. For the design reuse to be successful, data stored in IT applications have to be incorporated with employee knowledge (Mustonen & Harkonen, 2024). Product lifecycle management (PLM) systems as well as processes play a key role in facilitating documentation and design reuse methods (Pulkkinen et al., 2017).

1.1 Purpose of the study

This master's thesis is written for a Finnish technology company that provides solutions for energy and maritime industries. It is considered as a large company with more than 10 000 employees worldwide and net sales over five billion euros. For confidentiality reasons the company's name will not be mentioned in this thesis but it will be referred as "case company".

Order Specification Management system (OSM) was developed for the case company to improve productivity in project management. It unites Teamcenter and SAP smoothly and can be used to create, update, and delete Purchase Order Requisitions. Its main users are project engineers and project purchasers. In addition to project management, OSM also gives benefits to other stakeholders, such as, logistics, after sales, portfolio optimization, and customer. At the moment three different business units are using the application.

Currently some technical performance issues regarding OSM have been noticed by the case company which affect its responsiveness and usage. For example, the speed of certain processes is not at the desired level. Therefore, the main purpose of this thesis is to study the suitability of the OSM for case company.

1.2 Research questions and objectives

Objectives of this thesis are firstly to conduct a thorough literature review about lean manufacturing, engineer-to-order, product configurators, and product lifecycle management. Lean manufacturing is related to this research because later in the empirical study the wastes that OSM includes are examined. Engineer-to-order production strategy is useful to understand since OSM deals with ETO products. Furthermore, product configurators used in ETO business are explained because in case company they are used in generating inputs to OSM. Finally, product lifecycle management is a relevant topic in this thesis because OSM was developed for PLM purposes. In the end of the literature review, also Teamcenter software is explained because it is connected to OSM in the architecture.

In the empirical part of the study, the OSM will be studied by interviewing both employees who have been involved in its development and the employees who use OSM in their daily work. In the interviews with OSM's developers the emphasis will be on the reasons why OSM was developed as well as getting understanding of how it is linked to other IT systems. The opinions of OSM's users will be studied by sending a questionnaire that aims to discover their opinions of OSM's functionality and possible processing waste involved. After that a focused interview will be conducted with project engineers to discuss about the questionnaire results and get more comprehensive answers to some questions. Furthermore, processes of OSM will be described by creating flowcharts.

Based on the interviews and results of the questionnaire, recommendations for the case company will be given about the suitability of the OSM system. The goal is to get utmost objective perception about functionality of OSM. To achieve the objectives, following research questions are answered:

RQ1: *How can lean principles, product configurators, and product lifecycle management improve efficiency in engineer-to-order companies?*
RQ2: *What benefits have been sought originally by implementing OSM and what is the current state of the system?*
RQ3: *Is Order Specification Management fit for purpose for case company?*

1.3 Limitations of the study

This study focuses on the case company's order specification management application and the business units that currently use it. Therefore, the scope of this thesis is on the case company's marine business, but energy business unit is not included since the OSM is not used by them. Furthermore, there are limitations about the case company's products and components because all of them are not included in the scope of OSM. There are also limitations regarding research strategies. Because this research is conducted as a case study, the results cannot be generalized to other companies.

1.4 Structure of the thesis

This thesis includes five main chapters which are introduction, literature review, methodology, results, and finally conclusions. In the introduction's first sub-chapter the case company is first briefly described. After that OSM and purpose of the study are explained. Next sub-chapters describe research questions and objectives as well as limitations related to this study.

In the second main chapter a literature review about topics that are relevant to this study is conducted. Furthermore, the objective is to get answer to the first research question. It consists of three sub-chapters that are lean manufacturing, engineer-to-order, and product lifecycle management. In the sub-chapter the background of lean manufacturing is described. In addition, types of waste and lean principles are explained. In the second sub-chapter characteristics of engineer-to-order production are covered. Furthermore, product configurators and sales-delivery process are examined from point of view of engineer-to-order. Finally, the last sub-chapter covers the background of product lifecycle management, product structure, and product lifecycle management software.

In the third main chapter methodology for conducting the study is described. First the study approach is presented. After that the data collection and analysis methods are covered. Finally, reliability and validity of the study is examined.

The results chapter covers the results of the empirical research. First, the background of OSM is presented. After that processes of OSM are described. Next the developers' and users' opinions on OSM are presented. Finally, in the last sub-chapter the results of the focused interview are covered. The purpose of the chapter is to get answers to research questions two and three.

In the last main chapter, conclusions, the results of the whole study are summarized. Furthermore, it presents suggestions for future research, and managerial implications. Structure of the thesis is described in figure 1.

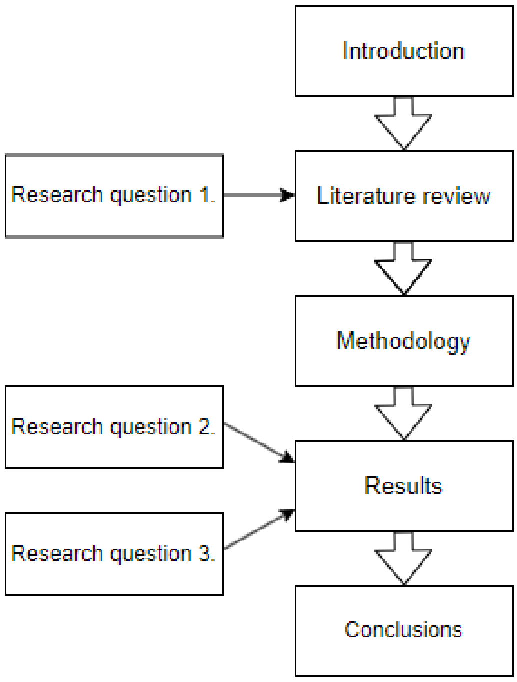

Figure 1. Structure of the thesis.

2 Literature review

This chapter provides thorough literature review about the theoretical concepts that are relevant to this thesis. The topics that are covered include lean manufacturing, engineer-to-order (ETO), product configurators, and product lifecycle management. References used in this section are from books and academic articles. The purpose of this chapter is to get an answer to the research question 1.

2.1 Lean Manufacturing

In 1950 Toyota's engineer Eiji Toyoda travelled to United States for three months to study Ford's production plant (Womack et al., 1990, p. 48). When Toyoda came back to Japan, he came to a conclusion with Taiichi Ohno that mass production that Ford used was not fit for Toyota. That was a starting point for Toyota Production System from which the lean production originated. Taiichi Ohno also named the seven types of waste, also known as muda, which lean thinking aims to eliminate (Womack & Jones, 1996, p. 15). Three terms that are essential in lean thinking are value, waste, and the process of generating value without wastage (Munro et al., 2022, p. 32). Cardenas-Cristancho et al. (2022) state that the main goal of lean is to reduce costs for the company while simultaneously improving the time it takes to deliver goods and services to customers.

Definitions of lean vary depending on author. According to Sousa & Alves Oliveira Silva (2024) lean manufacturing refers to philosophy or approach to work that aims to enhance operational quality without increasing rework expenses where findings from empiric and exploratory analysis are used to visualize industrial results. Shah & Ward (2003) define lean manufacturing as a multifaceted approach that incorporates various management techniques, such as management of suppliers, quality systems, and just-in-time in an integrated framework.

After lean was originally implemented in the automotive industry with a good success, also other industries, such as mining, steel processing, aerospace, and electronics manufacturing, started to apply lean practices (Mirdad & Eseonu, 2015). In engineer-to-order companies applying lean practices can benefit logistics by reducing defects and damage which reduces costs (Braglia et al., 2024). In addition, by using lean methods in engineer-to-order supply chains, efficiency can be enhanced throughout the whole design, production, and construction process (Schulze & Dallasega, 2023).

It is stated that successful implementation of lean increases customer value while enhancing company's profitability and behavior of employee citizenship. However, relatively few businesses are able to successfully apply lean. For example, it has been studied that merely 26% of lean projects were considered as successful in US manufacturing firms and similar results have been reported also in the U.K. Commonly the reasons behind the failures in implementing lean include choosing improper lean strategies or tools, relying exclusively on financial measures, or fail to align lean objectives with real-world practices.

2.1.1 Types of waste

According to Oppenheim (2011, p. 16) all activities in a work process can be classified into one of the three categories, which are value added (VA) activities, required non-value added activities (RNVA), and non-value added activities (NVA). An activity can be seen as value added if it modifies data or material, or mitigates uncertainty and the customer is prepared to pay for it. In addition, the activity must be performed correctly the first time. Activities that are required non-value added do not match the characteristics of a value added activity but they cannot be removed because they are obliged, for instance by law, agreement, or organization mandate. Finally, non-value added activities use resources without generating any value. Examples of non-value added activities include unnecessary reports, down time, and rework caused by defects.

The number of wastes in lean vary depending on authors but typically seven originally identified wastes are included (Munro et al., 2022, p. 42). Wastes listed by Likert (2004, p. 28-29) include overproduction, waiting, redundant transport, overprocessing or faulty processing, excess inventory, redundant movement, and defects. He also mentions eighth waste that is untapped employee creativity. Each type of waste is defined more precisely below.

1. **Overproduction.** Producing more items than is needed or producing them earlier or quicker than is needed. Overproduction results in redundant inventory which causes increased transportation and storage expenses. It also leads to excess work-in-process and overstaffing. Therefore, overproduction is considered as an integral waste as it is a source for many other wastes. Reasons why firms overproduce items include, for instance, lengthy setup times, and imbalanced workload (Munro et al., 2022, p. 42; Liker, 2004, p. 28-29).

2. **Waiting.** Employees waiting, for instance, for the following processing step or part or merely not having any work. Waiting is commonly caused by delays in processes or shipments, or missing employees. This kind of waste causes wasting of resources or demoralization of employees. Waiting can be eliminated by reducing setup times and accurately planning and executing scheduling (Munro et al., 2022, p. 42-43; Liker, 2004, p. 28).

3. **Unnecessary transportation.** Carrying items long distances which typically results in reduced quality. Root cause for this type of waste is often poor plant layout. A way to reduce this waste is to change the layout so that the machines that are used to produce a certain product are closer to each other (Munro et al., 2022, p. 44; Liker, 2004, p. 28).

4. **Excess processing or faulty processing.** Taking unnecessary steps to process items. This type of waste can be challenging to identify. Inefficient processing as

a consequence of sloppy design of tools and products leads to unnecessary motion and generating defects. Excess processing can happen both in the office and on the factory floor. Also producing higher-quality items than is required by the customer falls into this category of waste (Munro et al., 2022, p. 44; Liker, 2004, p. 29).

5. **Excess inventory.** Redundant raw materials, work-in-process, or finished items result in wastes, such as increased lead times, damaged items, and costs related to storages and transportation. Naturally, it is often necessary to have some inventory, but if a competing firm finds out how to reduce inventory and therefore cut down costs, business might be lost. Excess inventories are typically a symptom of problems like lengthy setup time, defects, or imbalances in production (Munro et al., 2022, p. 43; Liker, 2004, p. 29).

6. **Redundant movement.** Any unnecessary motion that employees must make in their work. Examples of redundant movement include searching or reaching for parts or equipment, and walking. This type of waste is usually a result of ineffective workplace layout (Munro et al., 2022, p. 42; Liker, 2004, p. 29).

7. **Defects.** Producing defective parts or fixing them. Fixing defectives causes wasting time and effort. Defects are often caused by inadequate maintenance of equipment, flaws in quality system, or inadequate training and instructions (Munro et al., 2022, p. 44; Liker, 2004, p. 29).

8. **Untapped employee creativity.** The last waste listed by Likert (2004, p. 29) that is defined as loss of time, skill set, ideas, improvements, and opportunities to learn as a result of not interacting or listening to your staff. Also, Munro et al. (2022) have mentioned this as an additional form of waste. They state that lean thinking can solve this problem by empowering teams to make changes in a culture that views mistakes as learning opportunities.

2.1.2 Principles of lean

Womack & Jones (1996, pp. 16-98) introduced five essential principles of lean which are value, the value stream, flow, pull, and perfection. Later the sixth principle, respect for people, was added (Oppenheim, 2011, p. 17).

1. **Value.** Value is the crucial starting point in lean which can only be specified by the customer. It is only relevant when presented in terms of a particular product that fits the needs of a customer at a right price at a right time. Therefore, it is pivotal to accurately, completely, and concisely capture the value of a task or program before resource costs increase in order to minimize needless rework. Value can be defined by disregarding current assets and technologies and using devoted product teams to rethink companies on a product line basis (Oppenheim, 2011, p. 17; Womack & Jones, 1996, pp. 16-19).

2. **The value stream.** A value stream is defined as the range of tasks that a company completes. Those tasks include, for example ordering, designing, manufacturing, and delivering items and services. The starting point of a value stream is typically the supplier's supplier and ending point customer's customer. There are three pivotal management tasks related to value streams, which are problem solving task, information management task, and physical transformation task. Analysing the value stream will most likely expose the three types of activities: VA, RNVA, and NVA (Munro et al., 2022, p. 47; Womack & Jones, 1996, pp. 19-20).

3. **Flow.** According to Womack and Jones (1996, p. 52) a prerequisite to making value flow is to define the value and identify the whole value stream. After those tasks are done, three steps should be taken next. First step is to concentrate on the actual thing and keep it in sight throughout the entire process. Secondly, conventional limits between jobs, careers, functions, and companies should be

disregarded to establish a lean company that eliminates all obstacles to the continual flow of a particular product or family of products. The final step includes rethinking particular work procedures and equipment in order to get rid of scrap, stoppages, and backflows of all kinds. This will allow the design, ordering, and manufacturing of the specific product to continue uninterrupted.

4. **Pull.** Pull principle means that the customer should be let to pull the item from the producer as needed instead of pushing products. That makes the sales forecasts useless since it gives the capability to design, schedule, and produce precisely what the customer wants at the right time. In manufacturing this principle is executed by using just-in-time delivery of materials and parts to the requiring station as well as the external customer. It is also important to be in touch with the internal customers to get the whole understanding about their requirements and expectations and to organize tasks, procedures, and deliverables (Oppenheim, 2011, p. 21; Womack & Jones, 1996, p. 24).

5. **Perfection.** The fifth principle is about pursuing perfection in every process by continuous improvement. It is crucial that the organization understands the difference between product and process perfection and provides resources in accordance with the need. Furthermore, transparency is important enabler for perfection since when all stakeholders in the lean system are able to see everything it is easier to find better methods to generate value (Oppenheim, 2011, pp. 21-22).

6. **Respect for people.** This last principle emphasizes that the essential resource of an organization is its people. The employees should not be afraid to identify issues honestly and figure out solutions to those problems. To create an environment that respects people, there should be mutually respective culture, open and sincere dialogue, and cooperative and synergistic stakeholder interactions (Oppenheim, 2011, p. 22).

2.2 Engineer-to-order

Engineer-to-order (ETO) is a manufacturing strategy for highly tailored items which must be thoroughly designed and engineered in accordance with specifications in the orders that customers submit (Amrani et al., 2010). Definitions of ETO vary depending on the scholars. According to Willner et al. (2016) some authors highlight that ETO denotes the creation of an entirely new product in response to a particular customer order while others say that it refers to the process of customizing already-existing items to meet consumer specifications.

ETO differs from other manufacturing strategies, such as Make-To-Stock (MTS), Assemble-To-Order (ATO), and Make-To-Order (MTO) because its decoupling point is further away from customer than in other strategies. Decoupling point refers to the point in which the company receives the customer order. In make-to-stock decoupling point is closest to the customer at the finished products in a centre of supply (Gosling & Naim, 2009). Furthermore, the goods are manufactured to stock in accordance with the demand forecasts (Zaerpour et al., 2009). Decoupling point in assemble-to-order is at the final phase of assembly. In ATO strategy there is a stock including standard components from which end products are assembled according to customers' requirements. (Brière-Côté et al., 2010). In make-to-order the decoupling point is at the fabrication and purchasing phase. MTO enables the customization of products by delaying the production to the point when customer demand is known (Ocampo et al., 2021). Furthermore, because of the postponement it is possible to reduce inventory holding costs. MTO strategy is commonly used in huge industries including for example clothing and furniture. Finally, in engineer-to-order the decoupling point is at design phase. Decoupling points in different production strategies are described in the following figure.

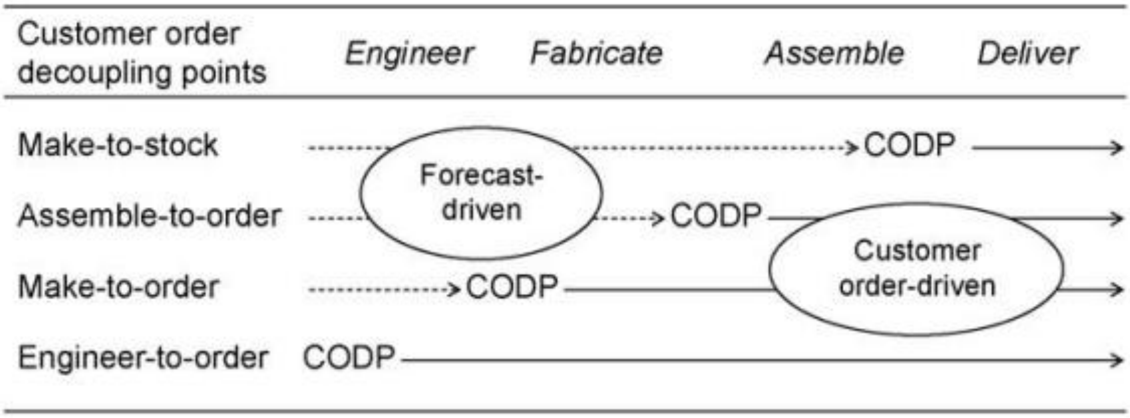

Figure 2. Decoupling points (Olhager, 2010).

In ETO the production control system and the production system both rely heavily on customer orders (Bertrand & Muntslag, 1993). Typically, ETO has been characterized by high degree of uncertainty regarding product's specifications, nature of demand, lead times for delivery and supply, and time frame of the production processes (Adrodegari et al., 2015). Bertrand & Muntslag (1993) mention that in addition to uncertainties ETO is also characterized by dynamics and complexity. Dynamics in ETO refers to the need to foresee remarkable fluctuations in things, such as sales volume. ETO company must cope with high fluctuations in sales volume and mix across the short- and medium-term. Those fluctuations cannot be managed by, for instance building capacity stocks because the production is determined by customer orders. Therefore, external flexibility is required from company in order to get by with these fluctuations.

According to Bertrand & Muntslag (1993) there are three major factors that make the ETO production complex. The first factor is related to the structure of the items' flow. The items' flow includes both physical and non-physical stage. The physical stage refers to activities, such as fabrication, assembling, and installation of machinery. The complexity of the physical stage stems from the complicated internal structure of assembly and fabrication departments. In addition, machines have complicated structure since they consist of thousands of parts. The non-physical stage includes activities such as designing, engineering, and planning of processes. Because the design processes are partially creative, it is challenging to formalize the work. In addition, the capacity needed for preparing quotations must be considered by the engineering department.

The second complexity factor is related to the situation's multi-project nature (Bertrand & Muntslag, 1993). Each customer order includes a series of activities of which some might be unknown at the first stages of the project. In the same departments several projects which are in different phases of completion must be controlled simultaneously. Project planning and coordination becomes complex when uncertainty in some project causes bottlenecks.

The last complexity factor is about the product's structure. The product might include thousands of parts of which some are customer specific and essentially unique. Because of that certain materials might need to be bought especially for a particular project. This implies that some materials that have long lead times must be bought in project's early stage when all the details about the product's structure are not yet fully known (Bertrand & Muntslag, 1993).

Willner et al. (2016) classify types of ETO into four different archetypes depending on complexity of engineering and average units sold per year. The archetypes are complex ETO, basic ETO, repeatable ETO, and non-competitive ETO. Complex ETO refers to traditional unique products that require high level of engineering complexity (> 2000 hours/unit) and are ordered in small quantities (< 750 units/year). Examples of products that belong to this archetype include nuclear power plants and ships. Lead times for complex ETO products are lengthy, and a significant portion of the overall lead time is attributed to order-specific engineering work. Complex ETO market has usually high barriers to enter which causes that there are only few companies operating. Since the work necessary to realize this kind of product is typically higher than the potential yields, there is little standardization or automation involved.

Basic ETO is characterized by low level of engineering complexity (< 2000 hours/unit) and low order quantities (< 750 units/year) (Willner et al., 2016). Products that belong to this archetype include, for instance, asphalt mixing plants. Because only a portion of orders need specific engineering and because order-specific modifications typically only affect a small number of product modules, Basic ETO products require little engineering effort. Lead times are medium or long varying based on the level of customization needed. In this archetype the degree of automation and standardization is medium.

Repeatable ETO refers to products with low level of engineering complexity (< 2000 hours/unit) and high order quantities (> 750 units/year) (Willner et al., 2016). Products that are included in this archetype are buses and elevators. Typically, these products are developed as make-to-order including several variants and can be altered at a later time upon customer's request. Lead times are usually short or medium. The order-specific engineering is handled by using exception handling methodology which means that engineering is provided as a service by a separate department. The degree of automation and standardization is high because the orders and processes are repetitive and engineering changes can be managed as MTO process exceptions.

The last archetype, non-competitive ETO, is characterized by high level of engineering complexity (> 2000 hours/unit) and high production volumes (> 750 units/year). According to Willner et al. (2016) non-competitive ETO occurs only in exceptional circumstances, such as when a pioneering firm acts in a quickly growing industry which lacks yet a dominant design. They state that placing a product in that archetype over an extended period of time is unprofitable. ETO archetypes are described in figure 3.

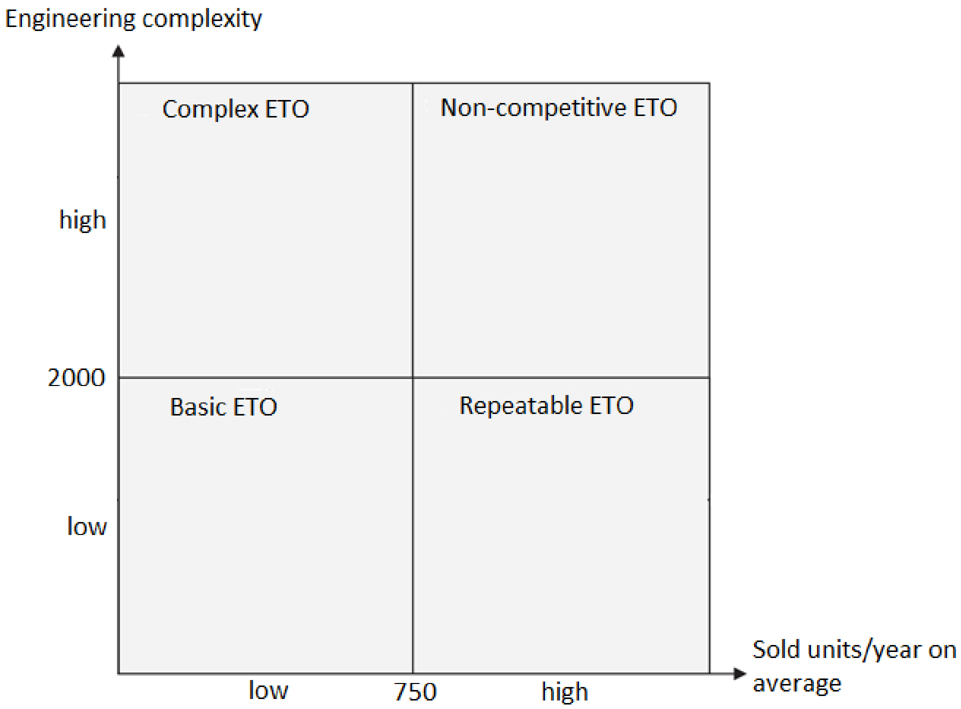

Figure 3. Archetypes of engineer-to-order (Willner et al., 2016).

2.2.1 Product configurators in engineer-to-order industry

Since customers are requiring more variety, there is a demand for reconfigurable processes and products (Kristiano et al., 2015). Product configurators are described as computer applications that assist in converting customer requirements into tangible building blocks and manage the legitimacy of provided product structures. One major challenge in ETO companies are “white spots” which means that product configurations are not complete and can change before production. This phenomenon has been discovered in many industries, such as manufacturing plant design, and civil engineering.

According to Willner et al. (2013) when implementing process and product configurators to engineer-to-order environment many areas of action need to be taken into account. Firstly, in order to establish a quick and effective product configuration process it is required to have a clear specification of parameterized item structures and possibly also families of modular components. Secondly, it is essential that the configuration system in question is completely integrated to existing IT infrastructure and interfaces to current IT systems along the chain of business processes are offered. Furthermore, it is necessary to guarantee close cooperation between all functional divisions throughout the chain of business processes.

Configurators can be classified as sales configurators or technical configurators based on whether the configurator is used in the order fulfilment process or the order acquisition phase (Cannas et al., 2022). The objective of configuration in the order acquisition phase is to convert customer’s needs of functionality and technical specifications into clear product representations that identify particular product variants. In the order fulfilment process the output of the order acquisition process is converted into complete set of specifications that are required to produce the particular variant. Technical configuration process is also referred as engineering configuration by some authors.

According to Cannas et al. (2022) ETO industries can achieve a lot of benefits by deploying a product configurator. The most commonly perceived benefit of deploying a product configurator is lead time reduction. Firms that don’t have product configurators must spend lots of engineering time into design work and cost calculations when customer asks for a quotation. Because product configurators can partly or completely automate that work both lead times and engineering work related costs are reduced. A study conducted by Haug et al. (2011) found that applying product configurators in ETO firms resulted in 83,7% lead time reduction to the quote creation process on average. Furthermore, hours required in engineering work reduced 78,4%.

In addition to reduced lead time and costs, ETO firms that have applied product configurators have also experienced improved product quality (Cannas et al., 2022). It can be explained, for instance by a decrease in hoc solutions, and configuration failures, and greater emphasis on incremental product improvements. In addition, some ETO companies have experienced improved quality in specifications during the order acquisition process. Also, the quality of the products that were provided to the customers was better than it had been before the configurator was used.

According to Cannas et al. (2022) there are some challenges that ETO firms encounter when deploying product configurators. The first challenge is related to re-designing the company's processes and items for configurability in the pre-implementation stage. For instance, items and components must have well specified interfaces and they must not cause redundant constraints to other components of the product's structure. For ETO companies it is very complicated and expensive to re-design the item offer. As a result, some companies that produce wide range of products can only afford to apply a product configurator for portion of their product range. However, if a firm achieves robust managerial and financial commitments it might succeed to incorporate its whole product offering on the configurator ultimately. The pre-implementation phase of the product configurator deployment is challenging also because the configurator has an effect on the main processes of the ETO firm, such as manufacturing and sales. Those core processes may also have to be re-designed which can take years.

The second challenge in deploying product configurators is related to managing the project of implementing a product configurator (Cannas et al., 2022). In this phase the most common challenges are associated with implementing complicated IT systems. Furthermore, some organisational challenges have been faced because implementation of a product configurator causes changes in employees' work tasks and roles. For example, change resistance have been noticed among employees who are afraid that they might lose their jobs since the configurator would automate several activities. In this scenario, it is crucial that the management is truly committed to the configurator implementation project.

Finally, the third challenge in deploying product configurators is related to the post-implementation phase. In this phase challenges rise, for example from expensive maintenance costs caused by configurators. Furthermore, there are challenges with the configurators' management in long term, such as updating configurators and expanding these updates to the whole company. After updates there is also need to check the validity of configurator knowledge which might demand for further expertise on configuration.

2.2.2 Sales-delivery process in engineer-to-order

In sales-delivery process of engineer-to-order companies product designers must constantly generate wide range of new designs to meet the specific needs of new customers (Brière-Côté et al., 2010). As a result, it is common that product variants are created separately for each project. Design reuse refers to reusing already approved design solutions while creating new product variations in accordance with specific customer needs. By incorporating design reuse in sales-delivery process many benefits can be achieved. For example, lead times can be reduced as well as customer specific design costs can be cut down.

According to Brière-Côté et al. (2010) there are three major stages in the sales-delivery process. Those stages are sales lead stage, quotation stage, and order stage. The main objective of the sales lead stage is to create a comprehensive quotation that accurately and meticulously captures the needs of a new customer. The sub-phase in the sales lead stage called sales configuration refers to the commercial perspective of the whole configuration procedure. The objective of the sub-phase is to transform requirements into standardized features by choosing and assessing the accessible parameters specified in the item family model. Since generic bill-of-material lacks a predefined structure for collecting special attributes, Brière-Côté et al. (2010) resolved this problem by presenting the idea of a parameter structure. The purpose of the parameter structure is to enable reusing of data from the product lifecycle in the early stages of sales-delivery process by making it easier to associate special attributes to identical attributes from the item family model. In the end of the sales lead stage the assessed parameter structure provides the requirements for the new item variant.

The next stage in the sales-delivery process is quotation phase (Brière-Côté et al., 2010). Its main objective is to assess the resource capacity needs for a new project as well as expenses with a manageable degree of risk for the producer. There are two sub-phases in the quotation stage which are proposal generation and customer evaluation. The purpose of the proposal generation is to further estimate lead-times and expenses concerning the design and utilization of new parts. The creation of estimate is supported by the assessed parameter structure including defining the unique features of the new product variant in connection to other comparable features from the item family model. The quotation phase ends when the order for the new item variant is verified.

The last stage in the sales-delivery process is called order phase (Brière-Côté et al., 2010). It consists of four sub-phases which are defining project, comprehensive order review, generating order specification, and customer-oriented design. In the first sub-phase project's activities, resource needs and lead-times are defined. It is also possible that the new item variant's elaborate design starts with the base product being immediately assigned to the configuration of the variant. In the comprehensive order review sub-phase, it is ensured that every customer need has been properly evaluated as well as selection requirements have been met. Technical structure of the fresh product variant is generated by gradually associating the variants that are reused with specified characteristics from the parameter architecture. In addition, design solutions from previously created modules and product variants are searched in order to exploit the advantages of design reuse to get ready for the upcoming customer-specific design of new products.

Next in the generating order specification sub-phase reused product variants with their comprehensive descriptions are provided to the as-designed setup of the fresh product variant. For the upcoming sub-phases, data regarding the present order is acquired, including details regarding the new components that need to be developed. The order specification's structure can in fact be perceived by the open variant architecture. The word "open" refers to the incompleteness of the variant's technical architecture because only base item and reused variants are configured. Connecting the initial specifications of new components to the ones that have already been configured in the open variant architecture gives design engineers broader structure for the last sub-stage.

Finally, new components' comprehensive design as well as release occur in the sub-stage called customer-driven design. Because of the work done in the earlier sub-stages to utilize item family model in evaluating special characteristics and connecting them to earlier design cases, it is now possible to reuse and adapt current design solutions efficiently. Once finished, the technical structure of the new item variant should serve as the engineering starting point for the later definition of other item structures.

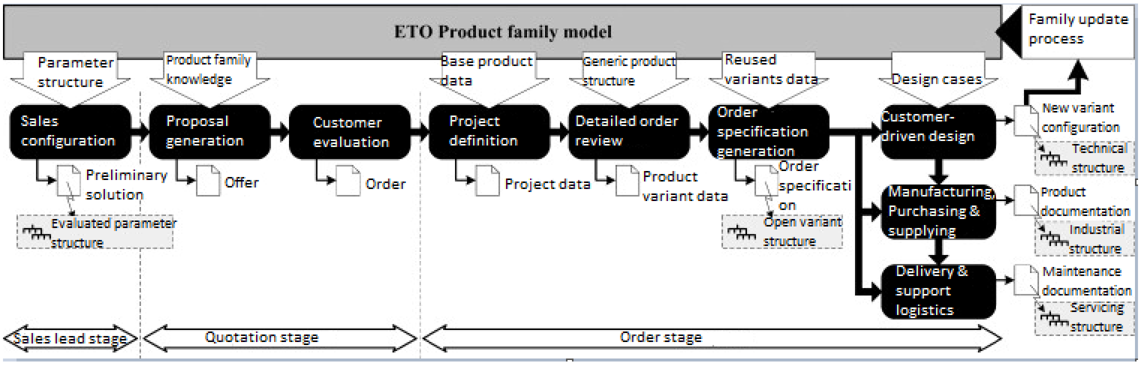

Figure 4. Sales-delivery process in ETO (Brière-Côté et al., 2010).

2.3 Product lifecycle management

Predecessors of product lifecycle management, engineering data management and product data management, were developed in the 1980s as manufacturing companies noticed that the quantity of design files created by CAD applications were expanding and they had to find a way to keep track of them (Sääksvuori & Immonen, 2008). Product data management made it possible, for instance to standardize products, maintain bill of materials, and determine the connections between assemblies and parts. Stark (2011) defines PLM as a business activity that enables management of firm's products throughout their entire lifecycles in the most efficient manner. Products to be managed can be either individuals or assortment of all the products produced a firm. The goal of PLM is to minimize costs related to products, enhance profits of the products, increase the product portfolio's worth, and make sure that both shareholders and customers get as much value as possible from current and forthcoming products. Furthermore, Sudarsan et al. (2005) mention that other objectives of PLM are to accelerate product development as well as enhance innovation in production. According to McKendry et al. (2015) in ETO company that manufactures ships, PLM in addition to other IT systems enables improved cost and quality.

According to Stark (2011) lifecycle of a product consists of five phases which are imagination, definition, realisation, use/support, and retire/dispose. In the first phase the product is merely an idea in minds of people. In the definition phase a thorough description is created based on the idea. In the realization phase's end, the product reaches its ultimate form which means that a customer can now use it. During the next phase, the product is in a customer's possession, and it is being used. Finally, in the retire/dispose phase the product is not useful anymore, and it is disposed by the customer. To ensure that the product yields good profits to the firm and everything works as supposed to, it is crucial that the product is managed in all those phases.

2.3.1 Product structure

Managing the product's structure is one of the key components of product lifecycle management (Brière-Côté et al., 2010). Also, Sääksvuori & Immonen (2008) state that product structure is the core of a PLM system in many ways. With the product structure, for instance components, configurations, and documents are linked to the product as well as to each other. The products and configurations in the PLM system are generated by attaching documents and components to one another via the product structure. Brière-Côté et al. (2010) define product structure as a group of objects and their connections that collectively demonstrate a structural feature of a product that needs to be specified for a specific reason.

According to Svensson & Malmqvist (2000) the Bill of Material (BOM) is the most prevalent kind of product structure in manufacturing companies. Stark (2011) defines BOM as a hierarchical structure illustrating the components of a final product. A BOM is hierarchical because it displays the end product, the components that make up the end product, and the components that make up the components that make up the end product and so forth. Various different BOMs can exist for the same item. For example, in Engineering Bill of materials, components making up the end product are described from the point of view of design. The Engineering Bill of Materials is created by designer after the item has been formulated (Chang et al., 1997). Another type of BOM is called Manufacturing Bill of Materials. It differs from Engineering Bill of Materials because it takes into account also assembly order and limitations. Furthermore, Manufacturing Bill of materials shows the shop floor assembly process for the product.

2.3.2 PLM systems

Through the use of PLM systems, companies aim to achieve clear benefits in terms of business development (Sääksvuori & Immonen, 2008). This implies that system projects typically have high expectations. A PLM system must effectively address goals, employee preferences, and the needs of the corporate environment. How well the system meets those expectations depends much on how successfully the user organization has articulated its own objectives and wants, as well as how well the commercial software that is currently on the market satisfies these requirements.

Product lifecycle management software offers solutions to organize and centralize all product development-related information, supply security protocols for information access, connect design and manufacturing processes, reuse the knowledge between a firm’s departments, and utilize software tools to assist with the PLM approach with other systems of the company (Enríquez et al., 2019). Teamcenter is a PLM software Created by Siemens (Zhan & Lib, 2022). By utilizing Teamcenter organized process design may fully and efficiently connect and organize different kinds of processing information for management. That removes the limitations of conventional process design and contributes to enhancing the design effectiveness and managerial capacity of firms' process design processes. In Teamcenter's Structure Manager firms can create, view, or edit the product's structure (Gecevska et al., 2013). Structure Manager makes it possible to easily visualize assemblies, compare visually, and examine tolerances and clearances. Screenshot of the Structure manager is described in figure 5.

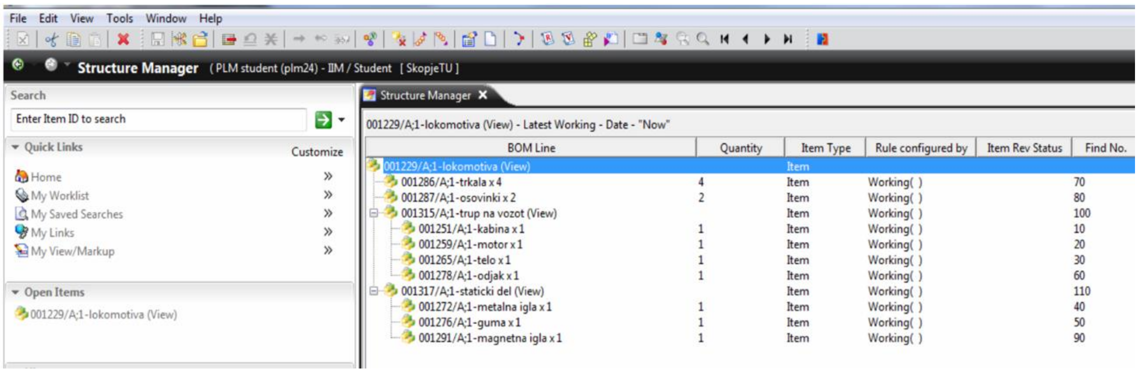

Figure 5. Structure manager in Teamcenter (Gecevska et al., 2013).

3 Methodology

In this chapter the methodology and approach for conducting the research is described. In addition, data collection methods and data analysis used in this study are explained. Finally, reliability and validity are examined.

3.1 Study approach

This study utilizes qualitative methods, such as semi-structured interviews, and analyzing materials provided by the case company. According to Golafshani (2003) qualitative research is a naturalistic method that looks for context-specific explanations for phenomena. Furthermore, in qualitative research the researcher does not try to tamper with the phenomenon in question. The qualitative methodology was selected for this study because in the qualitative research the main objective is to represent the perspectives and opinions of the participants (Yin, 2016, p. 9). Therefore, it is the most suitable method because in this thesis the main purpose is to study the participants' opinions on OSM.

The research strategy used in this study is case study. A case study looks into the specifics and complexity of a particular case, explaining its actions and contextual factors (Simons, 2009). According to Schell (1992) case study is the most adaptive type of research design because it lets the researcher to examine empirical events while preserving the comprehensive qualities of real-life incidents. It is common in case studies that data from several sources are used. In this study the event to be examined is Order Specification Management application used by the case company.

This study has some characteristics related to inductive approach. Induction means that the empirical data is gathered first, and theory is formulated after that (Saunders et al., 2007, p. 118). In other words, in inductive approach data would come before theory. This study started by conducting interviews and theoretical topics were decided later which is more inductive than deductive approach. In deductive approach testable hypotheses are created based on current theory and after that data is gathered to evaluate these hypotheses' feasibility (Janiszewski & van Osselaer, 2022). The most suitable approach for this research is abductive. The abductive research method aims to put forth novel theories. Unlike in deductive approach, in abductive approach there is not any official validation testing of theory (Janiszewski & van Osselaer, 2022).

3.2 Data collection

Primary data for the empirical study was collected by conducting semi-structured interviews, conducting a focused interview, and sending a questionnaire. The secondary data was collected by examining the case company's PowerPoint document. In that document processes of OSM were described and their execution times examined. In semi-structured interviews, also known as qualitative research interviews, the interviewer has a list of questions to be asked but the questions are not necessarily identical in every interview (Saunders et al., 2007, p. 312).

Interviews were carried out for two different groups of interviewees. The first group of interviewees included employees who were involved in development of OSM. This group included, for instance general manager, development managers, and manager of sales tools. Main focus with the first interviewee group was to get understanding of the origins of OSM, its evolution and current state. Summary of interviews with developers is described in table 1. Respondents 2, 3 and 4 were interviewed in the same Teams meeting so total number of individual interview sessions was 2.

Table 1. Summary of interviews with developers

Respondent	Title	Duration
1	General Manager	29 min 31 s
2	Development Manager	26 min 18 s

3	Manager, sales tools	26 min 18 s
4	Senior Development Manager	26 min 18 s

The interviews with developers were conducted in Microsoft Teams and recorded to make it possible to write down the interviewees' answers afterwards. The language used in the interviews was English. Because the interviews were semi-structured, the interview questions were not identical in every interview. However, there was a certain set of questions that were asked in every interview with the developers. The questions were as follows:

1. What were the key expected benefits or outcomes that were originally sought from developing OSM?
2. Were there specific problems or inefficiencies in existing processes that OSM was intended to solve?
3. Do you think the OSM currently works the way it was originally intended?
4. How has the OSM evolved since its initial implementation?

The second group whose opinions on OSM were surveyed consisted of employees that use OSM in their work regularly, such as project engineers. Those users' opinions on OSM were collected by sending a questionnaire created with Microsoft Forms. The questionnaire concentrated more on the user experiences and perceptions of OSM's usability. The questionnaire consisted of nine questions from which four were multiple choice questions, one rating scale question and four open-ended questions. An invitation to respond to the questionnaire was sent by email to 41 employees in April 2024. The recipients were given two weeks to respond to the questionnaire. To increase the number of respondents, a reminder was sent in the second week. The total number of respondents was 21 which corresponds to approximately 51% response rate. It took 10 minutes and 37 seconds on average for the respondents to complete the questionnaire.

After the response time for the questionnaire had ended and its results were analysed, a focused interview was arranged. In a focused interview, instead of asking detailed questions, the interview proceeds based on certain key themes (Hirsjärvi & Hurme, 2000, p. 48). This mainly frees the interview from the researcher's point of view and brings the voice of the interviewees to be heard. Invites for the focused interview were sent to twelve employees. In total, four project engineers participated in the interview. The interview took place in the case company’s office in Vaasa, and it was conducted in English. The interview lasted approximately one hour. Furthermore, it was recorded to enable transcription afterwards. The purpose of the interview was to dig deeper into the questionnaire results and to get more comprehensive answers to the questions.

3.3 Data analysis

After the response time was over, the results of the questionnaire were transferred to Microsoft Excel. Utilizing that software mean and median were calculated. Also, responses to the open-ended questions were analyzed in Excel. After that the Excel table was transferred to Microsoft Power Bi. With Power Bi different charts, such as pie charts and column charts were created. To analyze the results of the interviews all of them were recorded to make it possible to transcribe them later. In addition, an artificial intelligence tool was utilized in the transcription process.

3.4 Reliability and validity

According to Hirsjärvi & Hurme (2000, p. 186) reliability means that when studying the same person twice, the same result will be obtained both times. Another way to define reliability is that if two researchers come to the same conclusion the results are reliable. Rose & Johnson (2020) define validity as the process of assessing the findings’ veracity from the perspectives of the investigator, the respondents, or the study’s consumers.

Both reliability and validity originate from quantitative research (Hirsjärvi & Hurme, 2000, p. 186). The two types of validity are internal validity and external validity. Internal validity means how well the study results represent reality. External validity refers to the extent to which the findings are comparable to other groups or settings (Rose & Johnson, 2020).

One thing that can cause a threat to a study's reliability is participant bias (Saunders et al., 2007, p. 149). It means that the participants of the interview might say things that they think their managers want them to state. This kind of threat was addressed in the empirical study by making sure that the questionnaire was completely anonymous and any personal information was not collected. Furthermore, in the focused interview the participants were informed that any personal information about them will not be mentioned in the thesis and the recording will not be shared to anyone except for the interviewer.

Triangulation is used in this thesis to increase validity. Methodological triangulation refers to utilizing several methods for collecting data (Noble & Heale, 2019). In this thesis the data is collected by conducting interviews, sending a questionnaire, and analyzing case company's documents. Therefore, several methods are used in collecting data. In addition, different stakeholders of OSM are interviewed which increases the validity. Those who were interviewed also had experience with OSM so their opinions can be considered valid.

4 Results

In this chapter the results of the empirical study are presented. First the background of OSM and its architecture is described based on the interviews with developers. Next processes of OSM are being described. After that the developers' opinions of OSM as well as results of the questionnaire are presented. Finally, the results of the focused interview with project engineers are described. Objective is to get answers to the research questions two and three of this thesis.

4.1 Background of OSM

According to the first interviewee, the development of OSM started in 2015. It was the first web application developed in PLM area by the case company. It is stated that there were no references inside the case company or outside in the market for what the team was about to build. A lot of employees were involved in its development from different teams. There was also project manager, project owner, and steering committee included in the project. There have been lots of updates to OSM since its initial deployment. For example, originally it was developed as user interface on top of Teamcenter but subsequently it was made as a separate application. In addition, the OSM was first intended to be used only by marine solutions project engineers but today the user base has expanded further.

The main goal of developing OSM was that scope of delivery for customer solution projects would be managed and data would be stored in a PLM system. According to the first interviewee there were a lot of business challenges related to scope management that OSM was intended to solve. One major issue was that the previous system lacked ability to manage scope of supply in one place. In other words, there were several different sources from which the information was coming. These sources included Microsoft Excel, Microsoft Word, SAP PS, SAP ZIOS, and IOS configurator. That made the scope management inefficient.

Development manager stated that the main purpose of OSM was and still is to be able to follow the complete project scope and to be able to have a materialized, data structurized way of knowing what has been delivered to the actual end user and customer. Manager of sales tools added that OSM acts as a bridge between what are sold and what are purchased and delivered. In his opinion, OSM secures the data flow, ensures reusability, and covers the lifecycle of the project.

One main problem of the earlier way of working was related to documentation. Before OSM, there were lots of documentation to be managed as part of scope of supply. As a result, it was sometimes difficult to find the correct documents. The way of working then was time consuming, error-prone, and frustrating to project engineers who had to search and move information manually between different systems or views. Also, manager of sales tools team mentioned that before OSM the way of working was inefficient since project engineers had to open sales specifications, read them through and then retype the same information into for example SAP to place orders and also then retype the same thing over and over again potentially making the same thing different. The purpose of the application therefore was to remove complexity of the system and improve project engineers' user experience. Another major benefit that was got from OSM is reusability and availability of already existing data to be utilized instead of creating project specific data structures every time.

"We sometimes compared this to cooking. So basically you could say that you want to make a certain set of pasta bolognese you start of by actually figuring out every single time putting new things and trying if it tastes good instead of having the same recipe that you follow every time and buy the things you need and making the bolognese."

Architecture of the whole scope of supply management is presented in figure 6.

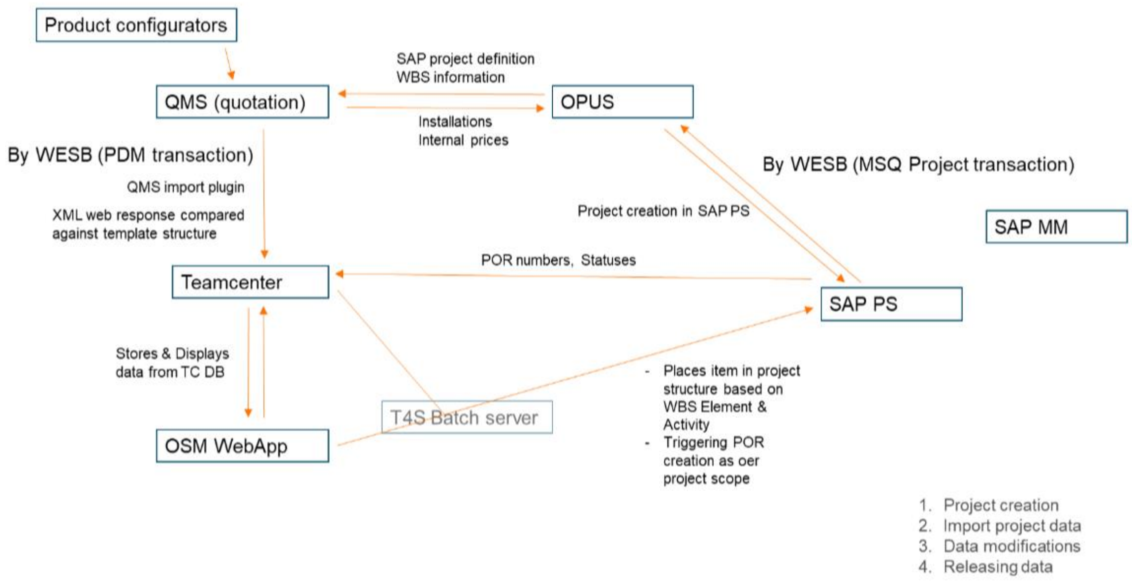

Figure 6. Scope of supply management.

The architecture starts with product configurators which are used to figure out what to sell to customer. In other words, product configurator is an application that defines rules based on portfolio. It tells what kind of engine can be delivered and what kind of auxiliary equipment are required or can be put into that engine. For example, a certain engine needs to be sold with gas valve unit and lng pack for it to function. Next sales team defines the scope of supply as a set of components to be sold, such as engine and fuel pumps. Based on that the technical specification will be generated that is sent to customer. If the customer accepts it, a contract will be received. According to manager of sales tools, product configurators actually read data directly from portfolio which is defined in Teamcenter. Therefore, he would also draw an arrow from Teamcenter directly to product configurators in the architecture.

After the contract is created, data can be transferred from QMS to OPUS and SAP which opens the project and allocates the sales budget to the WBS elements, network activities and elements. OPUS is an order processing system. It creates the project in SAP PS, fetches the project definitions and brings them to quotation management system (QMS). Figure 7 illustrates an example project in QMS.

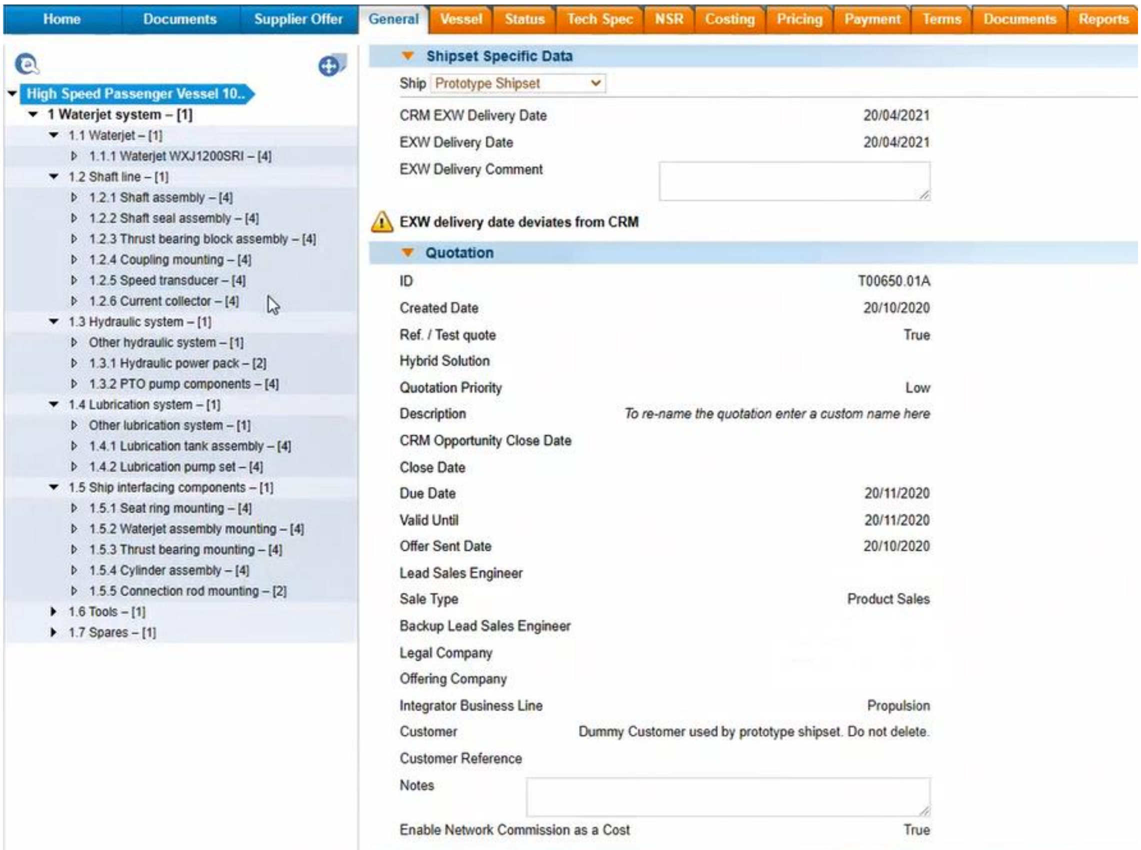

Figure 7. Screenshot of QMS.

Also, according to senior development manager OPUS is basically a controller that ensures that there is the same template that describes the project in Teamcenter and SAP PS. T4s batch server in the figure 5 is used to maintain materials that have been created. After the project has been created in Teamcenter and SAP it is now possible to start releasing purchase order requisitions for the specific materials in the structure and bringing them forward to the procurement part in SAP. Purchaser will then take over the process by transferring purchase order requisitions to purchase orders and procuring materials from vendors based on that purchase order. All the process steps are described in OSM in form of dashboard where user can see the status of the purchase order. For example, it can be seen if it is draft, confirmed, released, or delivered. In addition, in the main screen of OSM the user can see recent projects, work in progress items, and favourite projects list. The main screen of OSM is described in the figure 8.

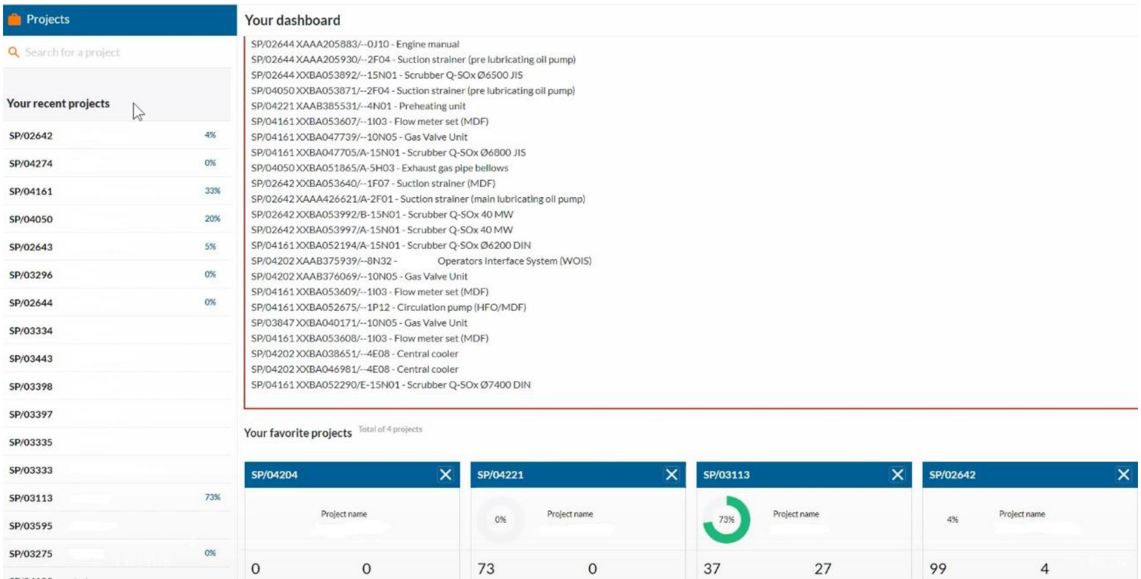

Figure 8. Screenshot of OSM main screen.

4.2 Processes in OSM

In 2022 case company arranged a go-and-see session in which they studied how much time it takes to perform two different processes in OSM. Furthermore, they compared how much time it takes to perform the same processes in SAP. From this session a PowerPoint file was created which is used as a secondary data in this thesis to create flowcharts. The first process is called creating a single purchase order requisition (POR) and it is described in figure 9. It was studied that the process takes 9 - 26,5 minutes to complete depending on the factors, such as whether the scope item is correct and material number in OSM matches TERPS material. The average time of the process was 17,75 minutes. Situations that were not taken into account in the time study were user errors, variances in speed of network and server, and time that users spend on reviews.

In addition, starting up the application and finding the correct project were not considered because they are activities that must be done only once.

Creating a single POR in SAP is simpler process since it only has four steps. Those process steps are as follows: create material component in WBS structure, copy item text from IPI to SAP long text, fill in POR data, and release and save. The time it takes to carry out this process is 3 – 5 minutes. Therefore, the average processing time is 4 minutes. Starting up the application and finding the correct project were not taken into account in this process either. Furthermore, disturbances in SAP server were not considered since they are very uncommon.

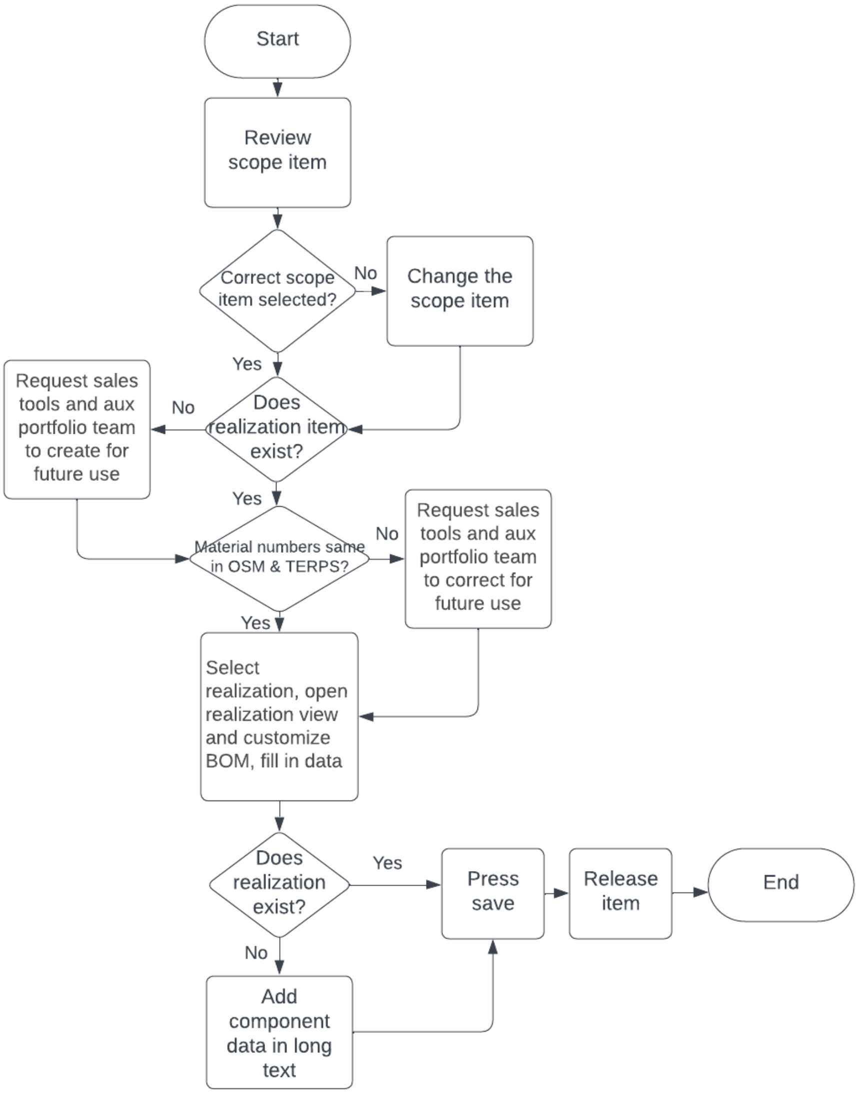

Figure 9. Creating a single POR in OSM.

The other process that is performed in OSM is called repeat vessel. It refers to the situation in which there is identical engine type with identical system components. Approximately 50% of the case company's portfolio belong to this category as for purchasing activities. This process only has three steps which are: copy scope item from source project to target project, press save, and release item. The whole process takes 2,5 – 5 minutes with average time of 3,75 minutes. The process is described in figure 10.

Figure 10. Repeat vessel process in OSM.

Carrying out similar process in SAP has three steps which are: copy scope network from source project to target project and release items, delete cost allocations from original networks, and press save. Total time that the process takes is 10 minutes. A point to be noted is that in OSM scope items must be copied one-by-one which means that total time spent per project depends on the extent of scope. For instance, if there are 15 different items it takes 56 minutes in total to copy them one-by-one. Instead, in SAP the total time spent per project is always 10 minutes regardless of the scope.

4.3 Developers' views on OSM

According to the first interviewee, general manager of engineering services, OSM is working well for that purpose it was originally developed for. She also states that the application is under continuous development and more use cases have been added to it since its initial release. In her opinion the development of OSM was started with right intention and it is developing to the right direction. Also, the other interviewees agreed that OSM currently works the way it was originally intended to. However, General Manager realizes that requirements in 2015 were different from today and more improvements are expected once people get used to something.

According to Senior Development Manager, OSM has not changed much during the years because the main concept is still the same as when it was introduced first. The changes that the application has received are mainly related to user experience. Also, userbase has evolved since today there are more employees using OSM than originally. According to the interviewees' estimates there are about 50-60 active users of OSM. As stated earlier, the main user group of OSM is project engineering. Other teams that use OSM include technical information. They are utilizing materials created through OSM in order to know what has actually been delivered to customers. Also, other interviewees agreed that the changes in OSM have been mainly related to user experience. Those changes include, for example, how data is presented, how it is treated, and how it is released to SAP.

4.4 Results of the questionnaire

To study the users' opinions about OSM, a questionnaire was sent to them via email. 21 users completed the questionnaire giving approximately 51% response rate.

The first question in the questionnaire asked about the respondent's business area. The respondents got to choose between two business areas which were Europe, Africa & America, and Middle East & Asia. The responses were quite evenly distributed between the two areas. Out of the respondents, 11 belong to Middle East & Asia business area whereas 10 belong to Europe, Africa & America business area. Hence, the percentage distribution between two business areas is 48% and 52%. The respondents' business areas are illustrated in pie chart in figure 11.

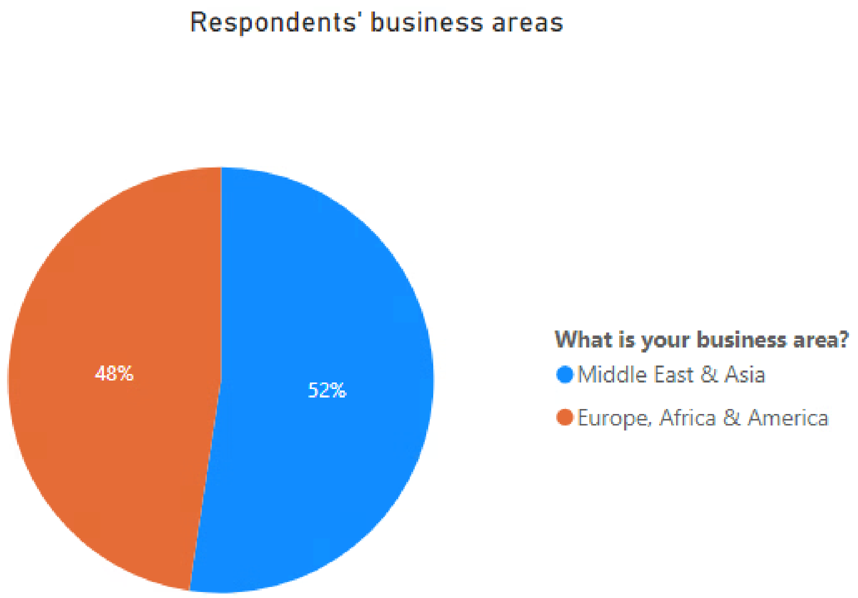

Figure 11. Respondents' business areas.

In the second question, the respondents were asked what products are included in their projects typically. Majority of the respondents stated that their projects typically include engines. Overall, 17 respondents mentioned engine in their responses resulting in 81%. The remaining 4 employees whose responses did not include engines responded that their typical project involve auxiliary equipment. In addition, there were 6 cases in which the respondent had both engine and auxiliary equipment in a typical project.

In the third question, the respondents' opinions on OSM's functionality were explored. OSM's functionality in the question was ranked in the scale from zero to ten. Zero indicated that OSM works very poorly whereas ten indicated that OSM works very well. The mean of the responses was 5,4 and median 6. The most common responses to the question were six and seven since both of them were chosen by four employees. None of the respondents chose zero or ten in the scale. There was a slight difference when comparing means between the two business areas. In Europe, Africa & America area the mean was 5,2 whereas in Middle East & Asia area it was 5,6. It indicates that respondents from Middle East & Asia area were slightly more satisfied with OSM's functionality. When comparing the most common responses between the business areas, employees from Middle East & Asia chose most commonly number six whereas in Europe, Africa & America numbers three, seven and eight were chosen identically many times. Clustered column chart in figure 12 illustrates how the responses were distributed among different business areas.

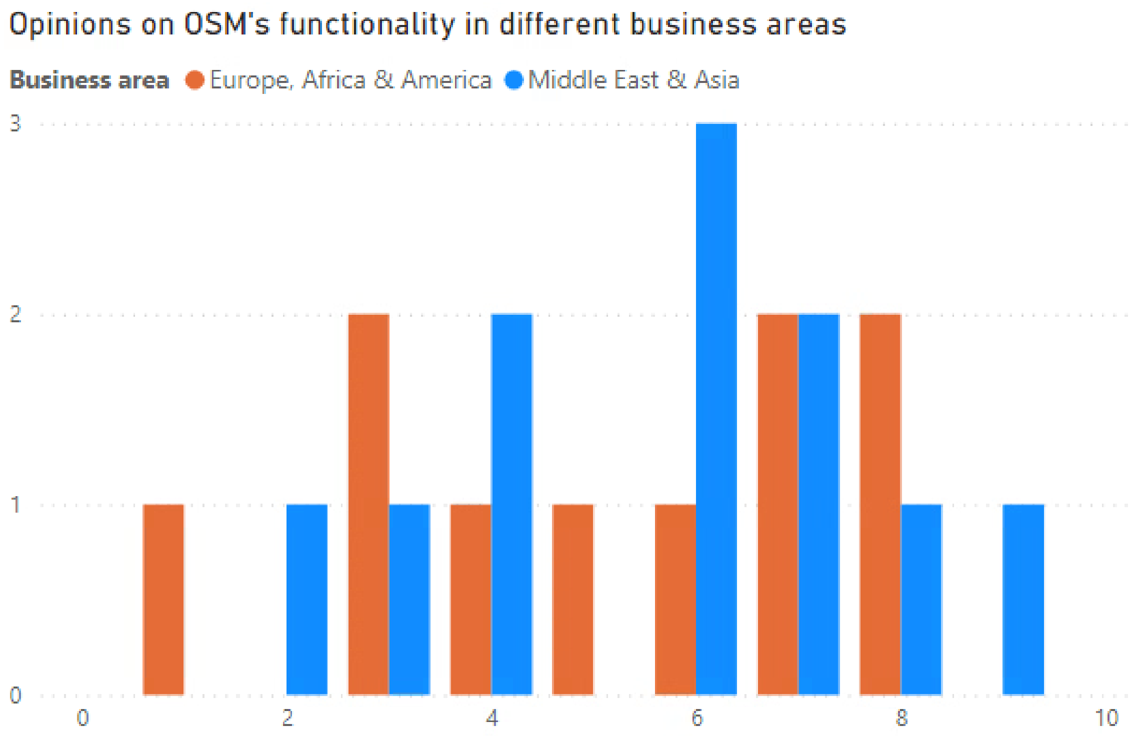

Figure 12. Opinions on OSM's functionality in different business areas.

In the next question, the respondents were asked how often they are typically using OSM in their work. The most common response was a few times per month since 48% of respondents chose that option. The second most common response was once per week with 19% of responses. 14% of respondents stated that they use OSM 2-4 days per week and options daily and never were both chosen by 10% of respondents. Figure 13 illustrates the distribution of responses to the question.

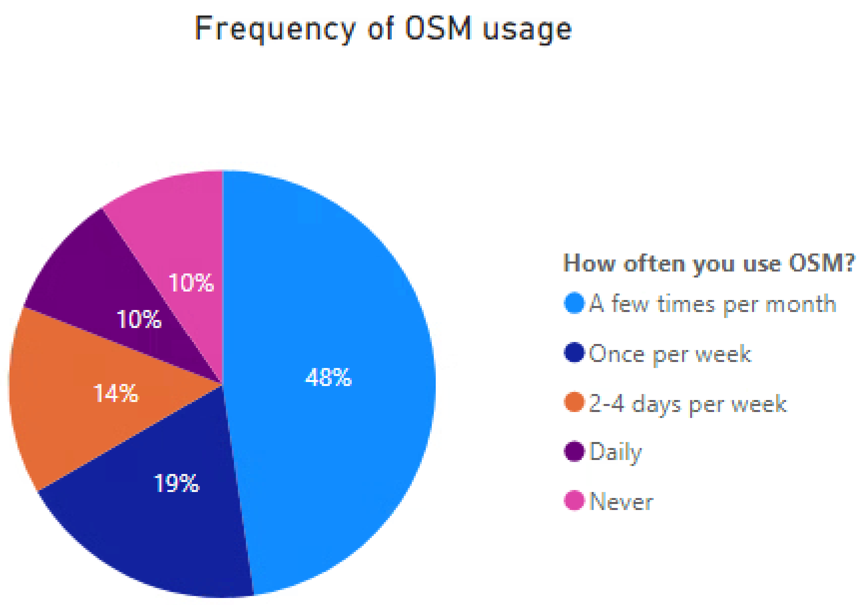

Figure 13. Frequency of OSM usage.

When comparing typical OSM usage in the two business areas it can be seen that in Europe, Africa & America the responses were more evenly distributed compared to Middle East & Asia. In Europe, Africa & America 30% of respondents use OSM 2-4 days per week, 20% a few times per month, 20% daily, 20% once per week, and 10% never. In Middle East & Asia business area, 73% of respondents chose option a few times per month, 18% once per week, and 9% never. When comparing how the frequency of OSM usage affects the respondent's opinion on its functionality, it can be noticed that the respondents who use OSM more regularly give higher score on its functionality on average. Both respondents who use OSM daily and once per week ranked its usability 6,5 on average. Instead, the respondents who stated that they never use OSM ranked its functionality 1,5 on average. Moreover, employees who use OSM 2-4 times per week ranked its functionality 4 and those who use it a few times per month gave it 6. The correlation between perceived OSM's functionality and its usage might be caused by the fact that employees that never use OSM think that it is not fit for purpose for them and use SAP instead.

In the question 5 the respondents were asked how many hours per day they use OSM on average. The responses distributed quite evenly between the options. The most common response was less than one hour since eight respondents or 38% chose that option. Seven respondents reported that they use OSM 1-2 hours per day which results in 33% of responses. Finally, six respondents or 29% stated that they use the application more than 2 hours per day. Pie chart in figure 14 illustrates respondents' OSM usage per day on average.

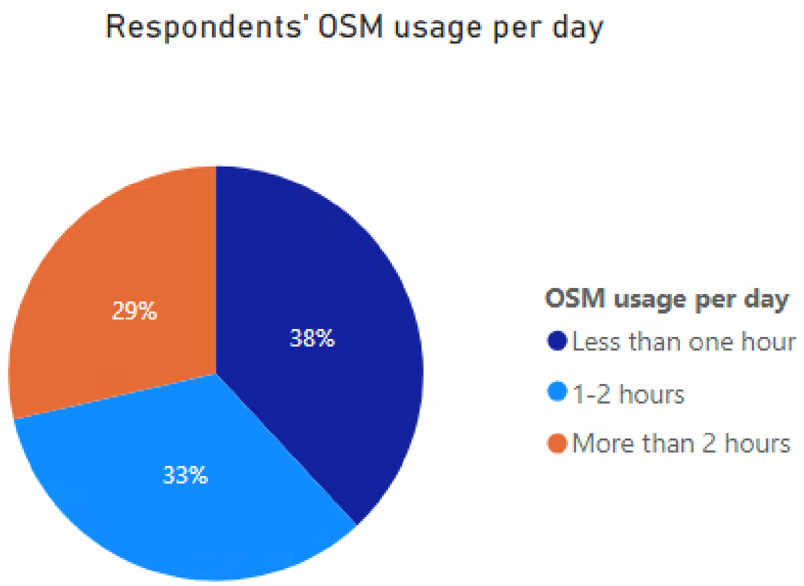

Figure 14. Respondents' OSM usage per day.

Similar trend could be noticed about respondents' OSM usage and their opinions about its functionality than in the previous question. Respondents who use OSM less than one hour per day gave its functionality 4,25 score on average. Those who use OSM 1-2 hours gave its functionality 5,86 on average, and employees who use it more than 2 hours gave its functionality 6,5 on average. It indicates that respondents who use OSM more per day think that it functions better than those who use it less often. There were small differences in OSM's usage per day between the two business areas. In Europe, Africa & America 40% of respondents use OSM 1-2 hours, 40% use less than 1 hour, and 20% use more than 2 hours. In Middle East & Asia 27,3% of respondents use OSM 1-2 hours, 36,4% use less than one hour and 36,4% use more than 2 hours.

The next question asked how much respondents consider there is processing waste during the time they use OSM. The most common response to this question was more than 30% since 43% of respondents chose this option. 33% of respondents thought that there is 0 – 15% waste during the time they use OSM. Finally, 24% of respondents chose option 16% - 30%. Respondents' opinions on processing waste are described in figure 15.

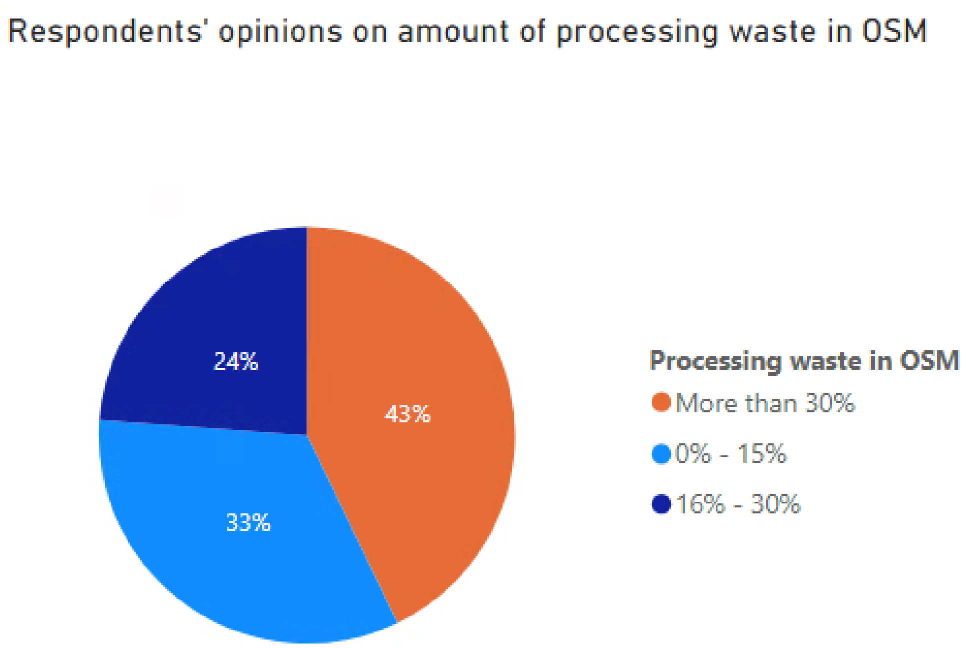

Figure 15. Respondents' opinions on processing waste.

When comparing responses from different business areas, it can be noticed that in Middle East & Asia responses were more evenly distributed between the three options. There 27,3% of respondents reported that there is 0% - 15% processing waste in OSM, 36,4% chose the option 16% - 30%, and 36,4% chose the option more than 30%. In Europe, Africa & America business area 40% of respondents thought that there is 0% - 15% processing waste, 10% chose option 16% - 30%, and 50% chose option more than 30%.

When comparing how respondents with different perceptions of the amount of processing waste thought about OSM's functionality, it can be seen that those who thought that OSM have more processing waste also gave OSM's functionality worse ranking. Respondents who thought that there is 0% - 15% of processing waste gave OSM's functionality average score of 7. Those who thought that there is 16% - 30% of processing waste ranked OSM's functionality 6 on average. Finally, the respondents who chose the option more than 30% gave OSM's functionality score 3,89 on average. Hence, there seems to be a connection between perception of OSM's functionality and amount of processing waste observed.

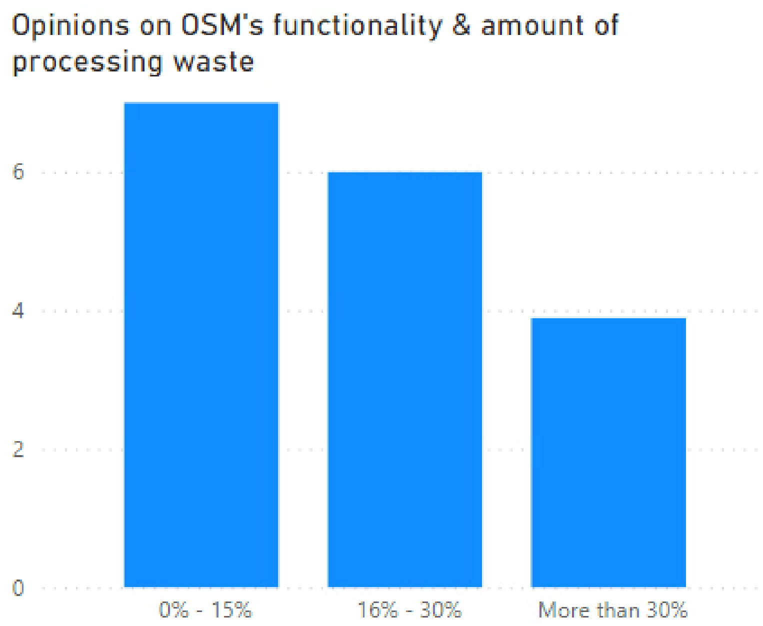

Figure 16. Opinions on OSM's functionality & amount of processing waste.

The next question in the questionnaire was open-ended in which the respondents were asked to specify what kind of waste they recognize in using OSM. The most common waste identified was slowness of the application since 13 respondents, which accounts for 62% of responses, mentioned it in their responses. The aspects that the respondents mentioned to be slow included adding, saving and releasing items, loading the data and issuing the data, website refreshing, and loading time. One respondent also claimed that slow data refresh is the result of the fact that the user is located in China. Other types of waste that appeared in the responses include system failures, freezes, and errors in the application. One respondent wrote exceptionally long answer to the question:

"*Note that usage of OSM depends on if you have a new project or not as this is only used to create PORs and majority of PORs are done only once in a project lifetime. If you have many projects in different phases you use OSM often, If you have many items in auxiliary equipment scope you will use OSM a lot. Depending on how often/seldom PEs get new projects affects who well OSM functionality is remembered, seldom you may forget how to use creates waste time when you need to check out certain issues. Majority of waste time is waiting for OSM to load/fetch solution data, revise/release times are very long. If you have already released and need to change you first have to revise=waiting time, edit data goes often fast, release=long waiting time + you can not release other items. If you have a large auxiliary scope you are forced to release during many days as there are always meetings, other hot matters arising that prevents you to continuously use OSM and finalize in one go or to finalize as far as possible. When not possible to release groups of items due to the nature of how the integration is built between OSM and SAP. Unreliability of OSM requires double checking in SAP to secure that all items have been transferred to SAP. If SAP is open it will terminate transfer from OSM to SAP and user needs to check who is logged into project on SAP side and ask them to jump out. A good tool but waiting time/errors kills all motivation among many users. If you leave creation of POR to a late stage users will face stress issues as it takes long time to create & release PORs."*

There was also one response that did not actually answer the question about identified waste:

"Tried to use it in two project. The more I used it the more it became obvious that it is not fit for purpose."

In the next question of the questionnaire the respondents were asked in which situations they think that OSM is working especially well. Two respondents left this question unanswered, so 19 responses were received in total. Several respondents thought that OSM is good for making purchase order requisitions. One respondent mentioned that OSM works well early in the morning or late at night. According to the same respondent that might be because the web system works well during those times. Some respondents also mentioned that idea with OSM is good, and one respondent liked the feature to automatically generate the full scope of supply.

“I think it is a great tool with a very user friendly interface, flexibility to include scope items from other projects (repeat items) and suggest realization items.”

In the last question the respondents were asked to give suggestions for improvement regarding OSM. One respondent left the question unanswered, so 20 responses were received in total. Several respondents mentioned that by making the application function faster it could be improved. Overall, seven respondents mentioned in their responses the slowness of the application. One respondent also stated that the application should be improved so that it would be possible to modify BOM material quantity after it has been released to SAP.

“Slowness will kill the idea with this program. Communication between Teamcenter and SAP needs to be faster.”

Multiple respondents also said that by improving the repeat vessel process in OSM the waste in the application could be reduced. One respondent gave especially comprehensive comment with background and suggestion for improvement:

"1. Background

1) Normally, genset is contracted as series(repeat) project.

2) It means that scope of supply and technical specification are same in all series(repeat) project.

3) However, PE has been creating the POR manually in OSM for every item for every series(repeat) project now.

4) If we could have the copy & paste function to use this from the first project to series(repeat) project, we can reduce the waste time much.

2. Suggestion

1) Add function of Copy & Paste for repeat project.

- (As-is) without copy & paste function: 280 items & 48hrs consumed for POR for ten (10) series project.

- (To-be) with copy & paste function: Needed only review for generated data. The saved waste time will be about 41.4hrs for ten (10) series project."

Another respondent that gave rather long answer mentioned first that responsiveness should be improved by enhancing development architecture or cloud server. Secondly, he added that multiple release operation should accept multiple release commands even though it releases one by one. Lastly, he thought that there are too many different reference numbers linked to a project which causes confusion and adds waste.

One respondent stated that they have meetings for key users regularly in which they push through improvement proposals for OSM. In his opinion to get major improvements there is need for a totally new approach on how the data is transferred to SAP. He also says that the current solution is not meeting the expectations.

4.5 Results of the focused interview

In the focused interview the purpose was to dig deeper into project engineers' opinions on OSM. In the beginning the participants were told about the results of the questionnaire's question 3 and asked their opinions on the average score that OSM's functionality was given. One of the interviewees thought that OSM is too slow application to get any higher points. After that it turned out that one project engineer in the interview does not use OSM at all but instead prefers to use SAP. He stated that: *"If I had to use it, I would question if it would be even possible to continue this work. I tried it in two projects earlier and it was absolutely disaster. Usually when you use a software, you get more familiar with it and then know how it works, but with OSM it was the opposite. The more I used it, the worse the experience became."*

The same interviewee also stated that he was involved in OSM's development and back then had five points that were important to him regarding that project. He said that in the opening session of OSM he noticed that none of them five essential things were on the agenda. As a result, he does not think that the application supports his work and therefore does not use it at all. According to him, one essential feature that OSM was supposed to include was opportunity to use material numbers that would have acted as kind of a serial numbers. That material number would have helped in defining the product and its specification. With that number it would have been possible to know exactly what has been delivered and everything could have been traced. That would have made it easier for after sales to find the exact product. He added that he has heard about several cases in which they have spent weeks trying to find out what has been delivered to the customer in order to offer correct spare parts to them. One interviewee also pointed out that in the other business units of the case company, such as energy business, they use material numbers but in their business unit it has been considered to be impossible. However, according to him it would be possible to use material numbers in their business unit as well.

The lack of identification of products has also caused problems in warranty department. One interviewee said that at least twice he has faced a situation where they have sent spare parts to the customer under warranty that have never been in the case company's scope of supply. The customer has thought that the spare part, for instance a filter has been made by case company because the engine has been made by them as well. Then at some point warranty department has contacted the interviewee and asked some details about the filter. At this point he has realized that the filter in question has not been made by the case company.

“We can trace everything based on this serial number. That was the brilliant, let's say, possibility of OSM and it was totally lost. And instead, you have a huge bureaucracy, and you get zero value out of it whatsoever.”

Considering processing waste of OSM the same types of waste were mentioned in the focused interview as in the questionnaire results. All the interviewees thought that OSM has issues with slowness and that it hinders its user experience. For instance, one interviewee stated that it took him a whole day to release PORs for one project. In addition, it was mentioned that it takes five minutes to create a new item in OSM. However, one new thing that came up in the interview was that according to the participants OSM was working faster earlier than today. According to one interviewee, in the beginning when they started to use OSM, developers did a lot for the performance but now it is back on track one again. Another new thing that came up was that the number of users has an effect on the slowness of OSM. More specifically, if there are a lot of people using OSM at the same time, it slows down the application. Also, in order to reduce the number of users, a user will be logged out of the application automatically after a certain time. According to one interviewee that happens because there is something fundamentally wrong with the architecture of the software or the programming language that is used. However, in his opinion the front end of the software seems to be fine. Furthermore, it was speculated that the slowness is caused by the integration between SAP and OSM.

In addition to slowness, another waste generating thing that came out in the interview was poor data quality. More specifically, when user opens OSM there is a database where data is very commonly incorrect. Therefore, often a first thing that must be done in OSM is to delete the wrong information and do modification which takes a lot of time and effort. According to one interviewee, when you use SAP instead of OSM there is a blank page which means that the user starts by filling in the correct information. He says that it is still more efficient and data safe than starting with incorrect information. The data comes to OSM from QMS and is created in the sales stage. It means that if there is wrong data in OSM, it is because sales engineer has selected wrong products.

"If you say how much of your working time are you making a difference creating value, it's close to zero. This is not value adding. Correcting mistakes and errors from other parties in the organization should not be, let's say, the main task."

Although the interviewees gave a lot of criticism towards OSM, there were also some positive things that were mentioned about the application. For instance, one interviewee said that more details about the products can be seen in OSM than in SAP. Those details include things like size of the product and also in SAP there was not possibility to do evaluation about why certain cost is connected. In other words, in OSM it is possible to check the correctness of the cost structure as well as to see exactly what kind of components sales have used for a product. Another positive thing about OSM that came up was that user always gets a consistent set of data that is not affected by what he is copying from somewhere else. Because when using SAP, the user needs to copy information manually from different sources and in some cases, it is not clear if the user is copying data from correct place. Therefore, with OSM the project engineer is not responsible of the data correctness but the person who is maintaining the data source. Also, it was mentioned that in OSM it can be reported more clearly what has been packed since there is one line in the packing list for each item. Earlier there could have been a lot of parts in the purchase order but it was not defined what has been really purchased.

Next the interviewees were asked if they know any applications that could replace OSM. They stated that SAP can be used instead of OSM. However, one interviewee noted that there is not future in using SAP because after sales wants to have tracking that cannot be done in SAP. Except for SAP the interviewees were not aware of any other application that could be used. One interviewee said that he does not care about what software they use as long as the data is correct and on time. According to him, there is no sense in trying to find another software as long as issues with data quality and speed are not solved.

“The basic is again wrong that we always tend to attack an issue not at the root of issue. But we make these kind of improvements, so to say, along the way somewhere. But we never focus on what was the issue from the beginning. Where should we start? And as long as we don't do that, every software, every process, everything we do is just another bureaucratic time consuming thing when we try somehow to cope with a real issue that we never solved and never addressed.”

Lastly the interviewees were asked if they have any other improvement suggestions for OSM. They agreed that they would be happy if the earlier mentioned issues with material numbers, speed, and data quality were fixed.

5 Conclusions

The purpose of this study was to get an objective understanding of the state of OSM application used in the case company's engineer-to-order business. Literature review section covered topics that were useful in understanding the issue that was researched. For example, understanding the lean manufacturing made it possible to interpret what kind of waste OSM users face when using the application. The three research questions in this thesis were:

RQ1: *How can lean principles, product configurators, and product lifecycle management improve efficiency in engineer-to-order companies?*

RQ2: *What benefits have been sought originally by implementing OSM and what is the current state of the system?*

RQ3: *Is Order Specification Management fit for purpose for case company?*

Answer to the first research question was obtained by conducting a literature review about the theoretical topics. From the literature review it was found that utilizing lean principles can reduce logistics costs and enhance supply chain efficiency in ETO companies. Product configurators can improve ETO firms' efficiency by reducing costs and lead time related to engineering work. Furthermore, they can improve the quality. Finally, by utilizing PLM, ETO companies can achieve cost reductions and quality improvements. Therefore, it was found that all above mentioned things can reduce costs in engineer-to-order firms.

Answers to the second question were obtained from the interviews with OSM's developers. According to them benefits that were sought from developing OSM included improving efficiency of scope management. Other objectives were, for example to know what has been delivered to the customer and to enable reusability. Also, OSM's users in the focused interview were aware that one goal with OSM was to identify products that have been delivered. However, according to them that feature is not working as it should be. Results of the empirical study revealed that the perceptions of the current state of OSM differ between its developers and users. The developers thought that the application is working well, and its development is going to the right direction. Instead, users' opinions on OSM were more negative since its functionality in the questionnaire got only 5,4 out of 10 on average. The application was criticized most about its slowness. Also, participants of the focused interview thought that OSM's development has gone worse over the years. Another thing that came up especially in the focused interview was the poor data quality. However, interviewees stated that the incorrect data is caused by problems in the sales stage, so that problem is not caused by OSM itself.

For the third research question there is not an unambiguous answer. The participants of the focused interview clearly thought that OSM is not fit for purpose. However, the results of the questionnaire indicate that there are also OSM's users who think that it is functioning quite well. The developers who were interviewed thought that OSM is fit for purpose. Therefore, whether OSM is fit for purpose for the case company depends on the respondent's perception of what was the primary purpose of developing the application. The case company's internal document in which processing speeds of OSM and SAP were compared revealed that OSM is slower in almost every situation. Hence, if the main purpose of developing OSM was in someone's opinion to increase the speed of processes, it is evidently not fit for purpose. Instead, if someone thinks that OSM's main purpose is to reduce the need for copying data from multiple documents and places, then it can be considered fit for purpose. The summary of OSM's expectations and current state between users and developers is presented in table 2.

Table 2. Summary of users' and developers' opinions on OSM.

Interviewees	**Expectations of OSM**	**Opinions on OSM's current state**
Developers of OSM	Managing scope of supply in one place, reusing existing data & knowing what has been delivered to end user	OSM is working as it was originally intended

Users of OSM	To have a material number which helps in defining and tracing the product	There are issues in OSM regarding speed, data quality, and material numbers

5.1 Managerial implications

This thesis provides an extensive explanation about OSM used by the case company's marine business. Based on the results of this study the company's management can decide what actions to take regarding the development of OSM to improve the project engineers' user experience and reduce non-value added activities in their work. Because the results of the questionnaire indicate that OSM's users' opinions about its functionality are relatively negative on average, it would be advisable to develop the application further. If the application's speed and data quality would be enhanced the project engineers' productivity would be increased and processing waste decreased. Also, other firms than the case company that are producing ETO products could be recommended to examine their engineering processes since the product specific engineering work typically takes a big portion of the overall lead time according to the literature.

5.2 Future research

Results of this thesis revealed that a lot of OSM's users think that the slowness of the application hinders its user experience. Therefore, there is a possibility for future research studying further what is causing OSM to function slowly. For example, it could be studied if the software's architecture or programming language are causing the slowness as the one interviewee guessed. Furthermore, in the focused interview the participants thought that employees working in sales create incorrect data. Regarding that, it could be studied how common it is that sales creates incorrect data and what are the root causes behind it. In this study only OSM's users were included in the focused interview.

Therefore, in the future research a focused interview could be arranged in which both OSM's developers and users participate so that also the developers' views could be heard about OSM's issues that project engineers mentioned. Furthermore, studies could be done also for other companies than the case company. Those studies could investigate how other firms that produce ETO products have handled their product specification processes and have they developed PLM software similar to OSM.

References

Adrodegari, F., Bacchetti, A., Pinto, R., Pirola, F. & Zanardini, M. (2015). Engineer-to-order (ETO) production planning and control: An empirical framework for machinery-building companies. *Production Planning and Control*, 26(11), pp. 910–932. https://doi.org/10.1080/09537287.2014.1001808

Amrani, A., Zouggar, S., Zolghadri, M. & Girard, P. (2010). Supporting framework to improve Engineer-to-Order product lead-times. *IFAC Proceedings Volumes (IFAC-PapersOnline)*, 43(17), pp. 102–107. https://doi.org/10.3182/20100908-3-PT-3007.00022

Bertrand, J.W.M. & Muntslag, D.R. (1993). Production control in engineer-to-order firms. *International Journal of Production Economics*, 30-31(C), pp. 3–22. https://doi.org/10.1016/0925-5273(93)90077-X

Braglia, M., Di Paco, F., Frosolini, M. & Marrazzini, L. (2024). A new lean tool to enhance internal logistics in Engineer and Design-to-Order industrial environment: plan for every order. *Production and Manufacturing Research*, 12(1), 2306836 https://doi.org/10.1080/21693277.2024.2306836

Brière-Côté, A., Rivest, L. & Desrochers, A. (2010). Adaptive generic product structure modelling for design reuse in engineer-to-order products. *Computers in Industry*, 61(1), pp. 53–65. https://doi.org/10.1016/j.compind.2009.07.005

Cannas, V.G., Masi, A., Pero, M. & Brunø, T.D. (2022). Implementing configurators to enable mass customization in the Engineer-to-Order industry: a multiple case study research. *Production Planning and Control*, 33(9-10), pp. 974–994. https://doi.org/10.1080/09537287.2020.1837941

Cardenas-Cristancho, D., Muller, L., Monticolo, D. & Camargo, M. (2022). Toward a holistic understanding of performance in Lean Manufacturing: a discussion on the relevance of its indicators, *International Journal of Lean Six Sigma*, Vol. 13 No. 5, pp. 1025-1057. https://doi-org.proxy.uwasa.fi/10.1108/IJLSS-10-2020-0163

Chang, S.-H., Lee, W.-L. & Li, R.-K. (1997). Manufacturing bill-of-material planning. *Production Planning and Control*, 8(5), pp. 437–450. https://doi.org/10.1080/095372897235019

Enríquez, J.G., Sánchez-Begines, J.M., Domínguez-Mayo, F.J., García-García, J.A. & Escalona, M.J. (2019). An approach to characterize and evaluate the quality of Product Lifecycle Management Software Systems. *Computer Standards and Interfaces*, 61, pp. 77–88. https://doi.org/10.1016/j.csi.2018.05.003

Gecevska, V., Anisic, Z. & Stojanova, T. (2013). Lean product lifecycle management approach. *International Journal of Industrial Engineering and Management*, 4(4), pp. 207–214. https://doi.org/10.24867/IJIEM-2013-4-125

Golafshani, N. (2003). Understanding reliability and validity in qualitative research. *The qualitative report*, 8(4), 597-607.

Gosling, J. & Naim, M.M. (2009). Engineer-to-order supply chain management: A literature review and research agenda. *International Journal of Production Economics*, 122(2), pp. 741–754. https://doi.org/10.1016/j.ijpe.2009.07.002

Haug, A., Hvam, L. & Mortensen, N.H. (2011). The impact of product configurators on lead times in engineering-oriented companies. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing: AIEDAM*, 25(2), pp. 197–206. https://doi.org/10.1017/S0890060410000636

Hirsjärvi, S., & Hurme, H. (2000). Tutkimushaastattelu: Teemahaastattelun teoria ja käytäntö. Yliopistopaino.

Janiszewski, C. & van Osselaer, S. M. J. (2022). Abductive Theory Construction. *Journal of consumer psychology*, 32(1), 175-193. https://doi-org.proxy.uwasa.fi/10.1002/jcpy.1280

Kristianto, Y., Helo, P. & Jiao, R.J. (2015). A system level product configurator for engineer-to-order supply chains. *Computers in Industry*, 72, pp. 82–91. https://doi.org/10.1016/j.compind.2015.04.004

Kumar, S. & Wellbrock, J. (2009). Improved new product development through enhanced design architecture for engineer-to-order companies. *International Journal of Production Research*, 47(15), pp. 4235–4254. https://doi.org/10.1080/00207540801939030

Liker, J. K. (2004). The Toyota way: 14 management principles from the world's greatest manufacturer. McGraw-Hill.

McKendry, D.A., Whitfield, R.I. & Duffy, A.H.B. (2015). Business and information management architectures for delivering product lifecycle management (PLM) in engineer to order (ETO) products. *RINA, Royal Institution of Naval Architects - International Conference on Computer Applications in Shipbuilding 2015, ICCAS 2015 - Papers, 2*, pp. 209–216.

Mirdad, W.K. & Eseonu, C.I. (2015). A Conceptual Map of the Lean Nomenclature: Comparing Expert Classification to the Lean Literature. *EMJ - Engineering Management Journal*, 27(4), pp. 188–202. https://doi.org/10.1080/10429247.2015.1082068

Munro, R. A., Ramu, G., & Zrymiak, D. J. (2022). The ASQ certified six sigma green belt handbook (Third edition). ASQExcellence.

Mustonen, E. & Harkonen, J. (2024). Commercial and Technical Productization for Design Reuse in Engineer-to-Order Business. *IEEE Transactions on Engineering Management*, 71, pp. 1271–1284. https://doi.org/10.1109/TEM.2022.3155791

Noble, H., & Heale, R. (2019). Triangulation in research, with examples. *Evidence-based nursing*, 22(3), 67–68. https://doi.org/10.1136/ebnurs-2019-103145

Olhager, J. (2010). The role of the customer order decoupling point in production and supply chain management. *Computers in Industry*, 61(9), pp. 863–868. https://doi.org/10.1016/j.compind.2010.07.011

Oppenheim, B. W. (2011). Lean for Systems Engineering with Lean Enablers for Systems Engineering. John Wiley & Sons, Incorporated.

Pulkkinen, A., Leino, S.-P. & Papinniemi, J. (2017). Transforming ETO Businesses with Enhanced PLM Capabilities. *Procedia Manufacturing*, 11, pp. 1642–1650. https://doi.org/10.1016/j.promfg.2017.07.315

Rose, J. & Johnson, C. W. (2020). Contextualizing reliability and validity in qualitative research: Toward more rigorous and trustworthy qualitative social science in leisure research. *Journal of leisure research*, 51(4), 432-451. https://doi.org/10.1080/00222216.2020.1722042

Saunders, M. N. K., Lewis, P. & Thornhill, A. (2007). Research methods for business students (4th ed.). Prentice Hall.

Schell, C. (1992). The value of the case study as a research strategy. Manchester Business School, 2(1), 1-15.

Schulze, F. & Dallasega, P. (2023). Barriers to lean implementation in engineer-to-order manufacturing with subsequent assembly on-site: state of the art and future directions. *Production Planning and Control*, 34(1), pp. 91–115. https://doi.org/10.1080/09537287.2021.1888159

Shah, R. & Ward, P.T. (2003). Lean manufacturing: context, practice bundles, and performance. *Journal of Operations Management*, 21: 129-149. https://doi-org.proxy.uwasa.fi/10.1016/S0272-6963(02)00108-0

Simons, H. (2009). Case Study Research in Practice. SAGE Publications Ltd.

Sousa, J. P. de. & Silva, J. I. A. de O. (2024). A bibliometric study of lean manufacturing and its relationship with sustainability. *Revista De Gestão E Secretariado*, 15(4), e3395. https://doi.org/10.7769/gesec.v15i4.3395

Stark, J. (2011). Product Lifecycle Management. Springer London.

Sudarsan, R., Fenves, S.J., Sriram, R.D. & Wang, F. (2005). A product information modeling framework for product lifecycle management. *CAD Computer Aided Design*, 37(13), pp. 1399–1411. https://doi.org/10.1016/j.cad.2005.02.010

Svensson, D. & Malmqvist, J. (2000). STRATEGIES FOR PRODUCT STRUCTURE MANAGEMENT IN MANUFACTURING FIRMS. *Proceedings of the ASME Design Engineering Technical Conference*, 1, pp. 377–386. https://doi.org/10.1115/DETC2000/CIE-14607

Sääksvuori, A. & Immonen, A. (2008). Product Lifecycle Management. Springer Berlin Heidelberg.

Willner, O., Rippel, M., Wandfluh, M. & Schönsleben, P. (2013). Development of a business process matrix for structuring the implications of using configurators in an engineer-to-order environment. *IFIP Advances in Information and Communication Technology*, 397(PART 1), pp. 278–285. https://doi.org/10.1007/978-3-642-40352-1_35

Willner, O., Powell, D., Gerschberger, M. & Schönsleben, P. (2016). Exploring the archetypes of engineer-to-order: an empirical analysis. *International Journal of*

Operations and Production Management, 36(3), pp. 242–264. https://doi.org/10.1108/IJOPM-07-2014-0339

Womack, J. P., & Jones, D. T. (1996). Lean thinking: Banish waste and create wealth in your corporation. Simon & Schuster.

Womack, J. P., Jones, D. T., & Roos, D. (1990). The machine that changed the world. Rawson.

Yin, K. R. (2016). Qualitative Research from Start to Finish. 2nd Edition. United States of America: SAGE Publications, Inc. ISBN: 978-1-4625-1797-8.

Zhan, X. & Lib, X. (2022). Cards and structured process planning based on Teamcenter. *Proceedings - 2022 2nd International Signal Processing, Communications and Engineering Management Conference, ISPCEM 2022*, pp. 284–287. https://doi.org/10.1109/ISPCEM57418.2022.00063

Appendices

Appendix 1. Questionnaire for OSM users

Questionnaire for OSM users

The purpose of this questionnaire is to gather data about user experiences of Order Specification Management. The data will be used in my master's thesis.

* Required

* This form will record your name, please fill your name.

1. What is your business area? *

   ◯ Middle East & Asia

   ◯ Europe, Africa & America

2. What products does your typical project include? *

3. What is your opinion on functionality of OSM? *

0	1	2	3	4	5	6	7	8	9	10

OSM works very poor ly — OSM works very well

4. Considering your typical work day, how often you are using OSM in your work? *

   ◯ Daily

   ◯ 2-4 days per week

   ◯ Once per week

   ◯ A few times per month

   ◯ Never

5. How many hours per day on average you use OSM? *

- ◯ Less than one hour
- ◯ 1-2 hours
- ◯ More than 2 hours

6. How much do you consider there is processing waste during the time you use OSM? *

- ◯ No waste at all
- ◯ 0% - 15%
- ◯ 16% - 30%
- ◯ More than 30%

7. Please specify what type of waste you recognize in using OSM. *

8. In which situations OSM works especially well in your opinion? *

9. Do you have any suggestions for improvement regarding OSM? *

Appendix 2. Invitation to a focused interview

Hi,

My name is Miika Alatalo, I am a master’s programme student at University of Vaasa. In my master’s thesis I am studying Order Specification Management (OSM). The purpose of this interview is to discuss about the results of the questionnaire that I sent in the last month. The interview is meant to be open so that the discussion can proceed freely within the subject area.

Best regards,
Miika