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Automation of Spare Part Lead Time Management for Valmet Flow Control

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ABSTRACT:
In the service business, managing working capital is crucial while meeting customer demands for faster lead times and better service. With global shortages of components, ensuring spare part availability for critical operations is pivotal. Customer satisfaction hinges on a robust spare parts supply chain. On-time-delivery is vital for profitability and customer satisfaction, as delays can have negative effect on customer satisfaction or in worst case drive clients to competitors. Maintaining short lead times require agile responses to demand fluctuations and dependable supplier relationship. Accurate lead times are essential for satisfying customers in this dynamic industry, where responsiveness and reliability are key to success.

This thesis was conducted for a large Finnish company specializing in critical flow control solutions for process industries. The purpose of this research was to automate the current spare part lead time update process, hence improving management of quoted spare part lead times. Additionally, to ensure the proper functionality of the newly created update process, tools for measuring and controlling the automated spare part lead time update process were created. The thesis concentrated on creating two artefacts that together solved the research problem presented in the thesis.

The research began by mapping out the current state of the process and recognizing the factors which needed rework and development by creating multiple process flowcharts. The semi-structured interviews conducted with the right stakeholders aided in understanding the current restrictions and parts of the current process that needed development. After mapping out the current state, the calculation logic for updating spare part lead time was reworked. After successful testing of the newly reworked calculation logic, a data integration between two data warehouses was built two ensure that the calculation always uses the most recent lead times in the ERP. These two artefacts, the new calculation logic and the data integration, form the new spare part lead time update process for the company.

This thesis was completed successfully. This was enabled by choosing a proper research method along with tools from other methods to adequately gather and analyze the available data and map out the existing parts of the process which needed development. The end result is as good as it can be at the moment. The future plan is to expand the automated update process to other warehouses that also serves global customers.

KEYWORDS: Design science, Lead Time Management, Service Business, Spare Parts

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TIIVISTELMÄ:
Varaosaliiketoiminnassa käyttöpääoman hallinta sekä asiakkaiden vaatimusten täyttäminen on ratkaisevan tärkeää. Kun komponenteista on maailmanlaajuinen pula, varaosien saatavuuden varmistaminen kriittisiä toimintoja varten on yrityksille elintärkeää. Oikea-aikainen toimitus on merkittävää kannattavuuden ja asiakastyytyväisyyden kannalta. Toimitusviivästykset voivat heikentää asiakastyytyväisyyttä tai pahimmassa tapauksessa ajaa asiakkaat kilpailijoiden luo. Lyhyiden läpimenoaikojen ylläpitäminen edellyttää nopeaa reagointia kysynnän vaihteluihin ja toimivaa toimitusketjua. Tarkat läpimenoajat ovat tärkeitä tällä toimialalla, jossa reagointikyky ja luotettavuus ovat menestyksen avaintekijöitä.

Tämä työ on tehty suurelle suomalaiselle yritykselle, joka on erikoistunut kriittisiin virtauksenohjausratkaisuihin eri prosessiteollisuuden aloille. Tutkimuksen tarkoituksena on ollut automatisoida nykyinen varaosien läpimenoaikojen päivitysprosessi ja siten parantaa varaosien läpimenoaikojen hallintaa. Lisäksi työssä luodun päivitysprosessin asianmukaisen toimivuuden varmistamiseksi luotiin erilaisia työkaluja varaosien automaattisen toimitusajan päivitysprosessin valvomikseksi. Työssä keskityttiin luomaan kaksi artefaktia, jotka yhdessä ratkaisivat työssä esitetyn tutkimusongelman.

Tutkimus aloitettiin kartoittamalla nykyinen päivitysprosessi sekä tunnistamalla päivitystä ja kehitystä vaativat tekijät luomalla useita prosessikaavioita. Yrityksen sidosryhmien kanssa tehdyt haastattelut auttoivat ymmärtämään nykyisiä rajoituksia ja nykyisen päivitysprosessin kehityskohtia. Nykytilan kartoittamisen jälkeen varaosien läpimenoaikojen päivittämisen laskentalogiikkaa kehitettiin vastaamaan yrityksen tarpeita. Päivitetyn laskentalogiikan onnistuneen testauksen jälkeen rakennettiin kahden tietokannan välinen dataintegraatio, jolla varmistettiin, että laskennassa käytetään aina viimeisimpiä ERP-järjestelmässä olevia läpimenoaikoja. Nämä kaksi artefaktia, uusi laskentalogiikka ja tietokantojen dataintegraatio, muodostavat yrityksen uuden varaosien läpimenoaikojen päivitysprosessin.

Tämä työ toteutettiin onnistuneesti. Tämän mahdollisti asianmukaisten tutkimusmenetelmien valinta, jotta dataa voitiin kerätä ja analysoida asianmukaisesti. Näin pystyttiin kartoittamaan ne prosessin osat, jotka vaativat kehittämistä. Tulevaisuuden suunnitelmana on laajentaa automatisoitu päivitysprosessi muihin varastoihin, jotka palvelevat myös maailmanlaajuisia asiakkaita.

AVAINSANAT: Design science, Lead Time Management, Service Business, Spare Parts

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Abbreviations and definitions

AI	Artificial Intelligence
B2B	Business-to-Business
BPR	Business Process Re-engineering
CPQ	Configure-Price-Quote, sales tool used in Valmet Flow Control
DO	Distributed Item
DSR	Design Science Research
DSRM	Design Science Research Methodology
DW	Data Warehouse
ELT	Extract, Load & Transform
ERP	Enterprise Resource Planning system
ETL	Extract, Transform & Load
F2F	Factory-to-Factory
FBA	Valmet Flow Control Factory Warehouse in Vantaa Finland
FFA	Valmet Flow Control Spare Part Warehouse in Vantaa Finland
IoT	Internet of Things
IPR	Intellectual property rights
ISD	Information System Design
KPI	Key Performance Indicator
M3	Enterprise Resource Planning system, used in Valmet Flow Control
MO	Manufactured Item
OTD	On-Time-Delivery
PO	Purchase Item

PTF	Planning Time Fence
SLT	Supply Lead Time
SR	Support request
SQL	Structured Query Language
VFC	Valmet Flow Control

1 INTRODUCTION

While industrial businesses are concentrating on effective working capital management, their existing clients are starting to demand improved lead times and service levels (Geetha & Ramesh, 2022, p. 797-798). In the current world situation, where there is a shortage of components and manufacturing materials, the availability of spare parts to customers for their critical operations must be secured. One of the key qualities that customers need is a robust supply of spare parts. Eventually, customer satisfaction and service level are directly related in the spare parts industry (Geetha & Ramesh, 2022, p. 797-798).

In the spare parts business, the efficient delivery of spare parts to the customer is critical for the profitability of the company's service operations (Antosz & Ratnayake, 2019, p. 212-225). If spare parts cannot be delivered on time or if the spare parts are not available to the customer, competitors have an opportunity to take advantage of the situation. In the worst case, the customer can turn to a competitor if it is not possible to meet the customer's needs in the specified time window (Antosz & Ratnayake, 2019, p. 212-225).

Due to high customer requirements, spare part lead times must be maintained low in the time-sensitive industry. In order to do so, the company must be able to respond quickly and flexibly to the changing demand for parts and supplies. In addition, the client must be able to rely on their supplier's ability to obtain the required part in a timely manner. Therefore, it is essential to provide accurate and dependable lead times for spare parts in order to maintain a high level of customer satisfaction in the dynamic spare part industry (Geetha & Ramesh, 2022, p. 797-798).

1.1 Company introduction and background

This research is conducted for Valmet Flow Control`s (VFC) spare part functions. Formerly known as Neles, the company was established in 1956 and Neles has a broad history of demerging and combining with other businesses. Neles was acquired by Finnish industrial conglomerate Rauma-Repola in 1982 (Valmet, 2023). Rauma and Valmet were merged in 1998 and the new company was named Metso in 1999. But all of this came to an end in 2020 after Neles separated from Metso and ran as an independent company for about a year. When Neles was acquired by Valmet on April 1, 2022, the VFC business line was formed (Valmet, 2023).

VFC is a Finnish business-to-business (B2B) company specializing in critical flow control solutions for process industries. As a world leader in its field, the company's clientele is growing all over the world and they work in a variety of industries where accurate fluid management is essential, such as mining, oil and gas, paper, pulp, and many more. Furthermore, these solutions enable companies to generate resources like gas, oil, and water that power our infrastructures and society. VFC`s product offering is very broad which allows valves to be configured to meet various customer needs. There are millions of unique valve assemblies depending on valve type, size, body material, trim material, actuator type, valve control type and so forth. VFC employed over 2800 people worldwide in 2022 and had net sales of around €700 million (Valmet, 2023).

VFC`s spare part functions have considerably grown in the past five years (Valmet, 2023). The synergy from the merger of Neles and Valmet has also accelerated the growth of Valmet Flow Control`s spare part functions. In addition, during the covid-19 pandemic most of the customer were doing only the necessary maintenance to keep plants operational. Complete shutdowns were avoided. Now customers have returned to normal shutdown intervals.

VFC spare part function is responsible for maintaining spare part data such as offering, lead times and pricing. In addition, spare part functions are the technical support for market area sales offices and service centers. When market area sales offices are planning the shutdown scope with the customer, spare part functions play a crucial role in the planning and providing the prices, lead times and deadlines for the customer to place the order to ensure the on-time-delivery (OTD) for the shutdown. Even though the OTD is very important for VFC and crucial for the customers` operations, VFC`s quoted spare part lead times can be outdated. This is due to incorrect data in the system and lack of automated process used for updating spare part lead times. There have been discussions in 2020 about updating the semi-automated spare part lead time update process to an automated process, but the project was put on hold because of covid-19.

1.2 Structure of the thesis

The thesis is structured in the following order: introduction, literature review, methodology, results, discussions and conclusions as illustrated in the Figure 1. The first and second chapter presents the case company, provides an overview of the research problem and the motivation for the thesis. Third chapter provides an understanding of the critical aspects of service business, benefits of process improvements and different methods of data integration. Fourth chapter describes the research method, data collection and data analysis process. Fifth chapter presents the design and development of the artefacts created in the study to answer the research problem. Final two chapters discusses the findings of the study and provides insight to future research.

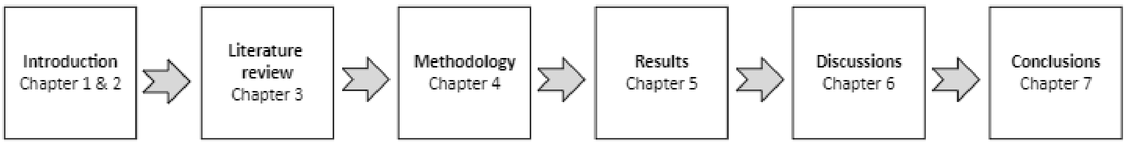

Figure 1. Structure of the thesis.

2 MOTIVATION AND PROBLEM IDENTIFICATION

This research is a master's thesis in field of engineering. The research leans more towards practical research than scientific research, since the aim of the thesis is to solve an existing practical problem. Although the work has been carried out as a practical research, the scientific contribution has been taken into account while writing the thesis. The semi-structured interviews conducted for the thesis created the basis for the theoretical framework which brings a scientific perspective to the practical work. Existing theories and models have been used in the work, so that the end result of the thesis is a functioning tool serving its purpose in the company.

Spare part businesses are dependent on customer satisfaction. Since lead times are so critical to customers, incorrectly quoted lead times can decrease customer satisfaction significantly (Antosz & Ratnayake, 2019, p. 212-225). Therefore, determining and calculating reliable lead times is an extremely important metric to both, the company and their customers. Especially in the current world situation, the importance of lead times is greatly emphasized in the spare part business. In short, inaccurate lead times can negatively affect overall customer relations and OTD (Antosz & Ratnayake, 2019, p. 212-225). The scientific motivation for this thesis arose from the above-mentioned points.

From scientific point of view the time-criticality and the complexity of the service or spare part business is nothing new. Nowadays the challenges are just different than 10 or 20 years ago. Recent covid-19 pandemic and the recent large scale armed conflicts around the world have had a significant impact on supply chains, the availability of raw materials and eventually component shortage (Sanjoy et al., 2021).

The covid-19 pandemic had only a short-term effect on the order volumes and the number of orders returned to normal very quickly. The ongoing war in Europe has not significantly affected the customer order volumes in VFC. Instead, both of these events mentioned above have had a collective impact: they have affected the availability of materials and components and thus affected the lead times, making them longer than usual.

Due to these challenges keeping lead times up to date is even more critical for the business.

The practical motivation for this thesis surfaced from the fact that current spare part lead time update process creates discrepancies in the spare part quotation and order processes. The time-sensitivity and dynamic nature of the spare part business creates a need for VFC`s service business line to develop their process regarding lead time quotation.

These mentioned lead time challenges are affecting other Finnish companies too. To support the scientific motivation of this thesis and the theory of lead times effecting company's customer relations and OTD, VFC organized a benchmark with a Finnish company Wärtsilä Corporation at their spare part facility in Vaasa, Finland. The most relevant questions from the benchmark are presented in Appendix 1.

Wärtsilä`s process of managing and maintaining spare part operations and data is quite similar to the process in VFC. Spare part lead times are updated semi-automatically and Wärtsilä has in-house and subcontractor spare part production. Using subcontractors to manufacture spare parts has increased lead times. The same negative effect on lead times can also be seen in VFC`s spare part lead times. Like VFC, Wärtsilä has also suffered from the component and material shortage. This has affected the customer delivery times and satisfaction.

The emphasis on OTD and lead time has grown in Wärtsilä`s spare part operations. Nowadays customers are more concerned about getting the spare parts on time rather than worrying about the spare part costs, which have gone up because of the material shortage. It was concluded that the customers are still loyal even though delivery times have been extended. This increases the need to maintain overall customer satisfaction.

2.1 Limitations, objectives and research problem

The objective of this thesis is to improve management of quoted spare part lead times by automating the lead time update process and thereby improve customer relations in VFC. Additionally, the goal is to create tools for measuring and controlling the created update process. In order to reach the objective, the current lead time management process and the relation between quoted spare part lead time accuracy and customer relations must be examined.

The research problem of this thesis is stated as:

How to optimally improve management of quoted spare part lead times in Valmet Flow Control`s service business line?

To reach the objective of this thesis and to solve the research problem, the following research questions must be examined and answered:

1. What are the challenges in the current lead time update process in Valmet Flow Control?
2. How can data integration between ERP ja sales tool produces more reliable lead times?
3. What is the most optimal way to implement data integration between ERP and sales tool?

The thesis is limited to VFC`s spare part warehouse functions in Vantaa spare part facility, which is serving vast majority of the global spare part deliveries in VFC. Currently it would be too complex to improve the whole global service business lead times. Additionally, the new lead time calculation model for spare part items is limited to items with static lead times. Extending automatic lead time management to other supplying spare part warehouses is a future project.

The work is limited as mentioned above, so that the implementation would be as efficient as possible. This research will act as a foundation for the automation of other warehouse lead times. Based on the comments of the people interviewed for the work, it made sense to limit the thesis in such manner.

2.2 As-Is process

For the sake of confidentiality, and intellectual property rights (IPR), from this point on the data warehouses will be addressed as DW and not with the actual names. VFC`s spare part business depends on customer needs. Figure 2 shows the simplified version of the spare part quotation process in VFC. The process begins with the customer inquiry to the company`s sales engineer. The sales engineer then checks the price and the lead time for the item(s) included in the inquiry. If all the data is available in the sales tool (CPQ), the sales engineer will send a quotation to the customer. Now customer can place an order based on the quotation. The order is then validated by the order confirmation team and the customer receives an order confirmation.

If all or some of the data is not available in CPQ for the item(s), the sales engineer sends and support request (SR) to the quotation team to add the missing data. Once the data is fixed in CPQ the sales engineer can send a quotation to the customer and the process continues as described above.

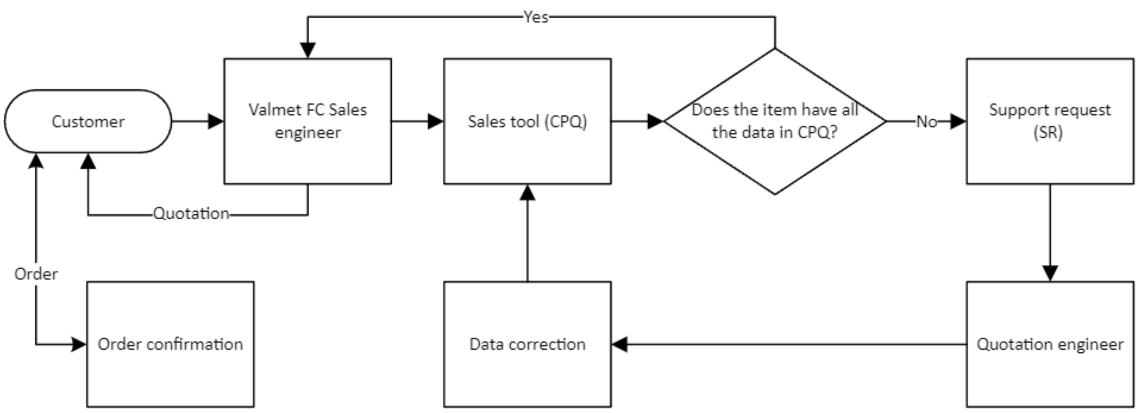

Figure 2. Spare part quotation process flowchart.

The problem with the quotation process has turned out to be the available lead time data in CPQ. The existing spare part lead time data can be outdated since it is not updated frequently. The spare part lead time will not be validated by anybody until the order confirmation stage. By then the customer has already received an incorrect quotation. Only if the lead time data is missing for the item(s) in CPQ, it will be verified using enterprise resource planning (ERP) system M3. The system consists of all item data including the spare part lead times.

Originally, the spare part lead time update has been done for individual items when someone has noticed that there is a wrong lead time information in the system. For new enriched items the lead time is manually updated in M3 and CPQ, which is why the lead times are usually valid. The process for enriching items is presented in Appendix 2. Mass lead time update for spare part items to M3 and CPQ have been done once or twice per year using Excel tools as illustrated in Figure 3.

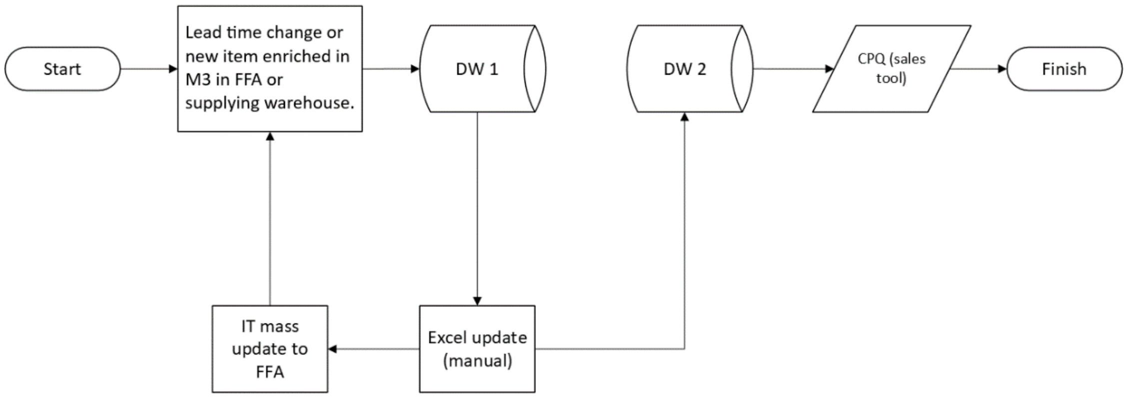

Figure 3. As-Is spare part lead time update process flowchart.

The original manual update process is very laborious and time consuming because it has to be done using four different Excels that use exported spare part lead time data from data warehouse 1 (DW1). This is because the first step of the update (for example, lower-level items in a set) must be completed before the next update (for example, top level item spare part set) can be done. Also, the Excels do not work properly for every item. Therefore, the original update process required a lot of assurance and manual checking for the items that the Excels could not calculate the lead times for. The above mentioned factors together with the earlier mentioned fact that there are millions of unique valve assemblies, make the original spare part lead time update process very labor intensive.

The motivation for this thesis arose from the fact that it is challenging to keep the spare parts lead times up to date. In addition to the availability issues with materials, there are also issues with the systems used in the spare part business affecting the lead time updates. The problem is that there is no data integration between the Enterprise Resource Planning system (M3) used to manage the entire commercial data and the sales tool (CPQ), which is used by quotation and sales engineers. The following example demonstrates daily issues faced by the spare part quotation and order confirmation team.

Case example:
In sales tool (CPQ), an item has a 7 -week lead time. However, in the enterprise resource planning system (ERP) M3 in the factory warehouse (FBA), the purchase time for the item is actually 105 days (15 weeks). The item has previously been purchased from Finland, but at some point, the purchase team has decided changed the supplier. There has been no exchange of this information about the supplier change and the extension of the lead time, and nothing triggers the change to happen automatically in M3 in the spare part warehouse (FFA) and also in sales tool CPQ. For this reason, in CPQ the item still has the old lead time information and sales engineer has quoted the item to the customer with the outdated lead time.

Now the lead time for the item is longer than what the customer has been originally quoted. This causes discussion between the factory and the sales and between the sales and the customer. Of course, the extended lead time for the customer is bad news. If the customer's need was for a planned shutdown and the item was needed at a particular time, it would delay the entire shutdown. Of course, the purchase of the item can be tried to advance, but this means further clarification, discussions and possibly additional costs for quick delivery.

In other words, if there is an alternation made to an item in any of the factory warehouses globally in M3, nothing triggers the change to also occur in the spare parts warehouse (FFA) in M3 or in the CPQ. For example, if the price, the manufacturing time or the supplier of an item changes, the information will not be automatically updated in all systems needed. This leads to sales engineers possibly quoting outdated lead times causing issues afterwards. These possible mistakes are noticed only after the quotation is sent to customers, causing the customer to receive false information. Ultimately this lowers customer satisfaction and customer engagement, which is why the problem between the systems creates a need for process improvement.

2.3 To-Be process

The expected result of this research is to create an automated calculation tool for updating spare part lead times in Microsoft SQL server ecosystem used in the company. The tool will update the planning time fence (PTF) or supply lead time (SLT) value in FFA in M3 and the lead times in CPQ when changes in items occur in M3. For example, if the purchasing or machining time changes in the manufacturing or delivering warehouse in M3, the lead time updates automatically to CPQ. If the item is distributed from Vantaa factory warehouse (FBA) to FFA or if the item is manufactured in FFA, the PTF value would be updated. If the item is a distributed item from an international warehouse, the SLT value is updated to FFA warehouse in M3.

In order to create the automated update process, data integration between data warehouses which store the M3 and CPQ data must be established. Creating a bridge between the two data warehouses ensures that the latest data is used for calculating the spare part lead times. The goal is to provide the most accurate static lead time for customers. Dynamic lead times are not in the scope of this research since it can take from weeks to months from the quotation to the actual order and by then, the quoted dynamic lead time has most likely changed. In addition, a set of rules must be defined on how the lead time value is calculated for different types of spare part items. Also, tools for measuring and controlling the update process are needed.

In the interest of creating the automated calculating tool and the data integration between the two data warehouses, interviews with the right stakeholders must be conducted. Interviews are needed to better understand the complexity of the spare part lead times, what options there are for the data integration, are the two existing data warehouses even compatible for a data integration and does the integration of the two data warehouses need any additional software to work efficiently.

A draft of the To-Be spare part lead time update process is presented in Figure 4. As mentioned earlier, a data integration in the update process is a must. The spare part lead times cannot be updated automatically and efficiently without a data integration and of course without a new reworked automated calculation logic.

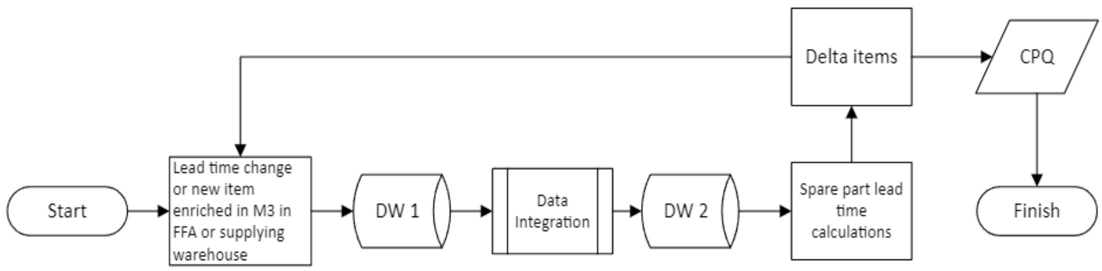

Figure 4. Draft of the To-Be spare part lead time update process.

If the automating process is successful, it benefits the whole spare part business in Valmet Flow Control. For instance, the cycle of updating lead times becomes more frequent, which improves the accuracy of the quoted lead times and this in turn improves customer satisfaction. Also, the process improvement will lighten the workload of the order confirmation and the spare part quotation teams, meaning that their resources are available for other more important tasks.

3 IMPLEMENTATION OF DATA INTEGRATION IN SPARE PART BUSINESS

This chapter provides an understanding of the critical aspects of service business, benefits of process improvements and different methods of data integration. The main focus is on the service industry and data integration. From the point of view of this research it is necessary to understand the true definition of service business and what critical functions it includes.

Since one of the goals of this research is to build a functioning bridge between two data warehouses, this chapter will introduce different methods for implementing data integration. Additionally, the concept of information system design (ISD) will be introduced since the main goal of this research is to improve an existing information system related process.

3.1 Complexity of service business

In the modern business world, the service business side of the company is viewed as a crucial component of both the overall business and new business opportunities, and they are particularly becoming a crucial component of the company's profit-making entity (Antosz & Ratnayake, 2019). Many businesses have switched their attention to expanding their service offerings and meeting the requirements of their customers. An advanced service business can provide a long-term reliable and long-lasting revenue flows to a manufacturer and its service network. It can also assist in building strong customer relations and loyalty (Zhang et al., 2021, p. 1-2; Geetha & Ramesh, 2022, p. 797-799).

According to Antosz & Ratnayake (2019), across industries, the after-sales market's potential has begun to gradually emerge. The service industry has anticipated a future market that will be both strategically significant and pivotal for future competition.

Successful service businesses have observed that increasing customer satisfaction is the main factor to increase the possibility of the repurchase of new products. Thus, it can be said that the functioning supply of spare parts is one of the crucial elements in guaranteeing that clients receive high-quality service levels (Antosz & Ratnayake, 2019).

Bacchetti & Saccani (2010, p. 5-7) claim that customers have increasingly started paying attention to the quality of service levels and aftersales services, since the share of extra sales and replacements has progressively grown. Although, when customers are making decisions whether to buy a new product, effectively operated aftersales services have also become a crucial aspect of the purchase decision. Therefore, it can be said that the service business will grow to be a significant source of income for many companies.

3.1.1 Spare parts

Spare parts, also known as replacement parts, are components or items intended to repair or replace a specific part of a machine or device. They are manufactured to match the original specifications and functionality of the parts they are intended to replace and are used when the original parts are worn out, damaged, or used up. Spare parts can be found in multiple industries, such as automotive, defense, and manufacturing, among others. Examples of spare parts include engine parts, electrical components, mechanical components, and structural parts (Pawlowska-Kalinowska, 2017, p. 53-62).

Because of their nature, spare parts play a critical role in the maintenance and repair of machines and devices. They ensure that the equipment continues to function optimally and reduces downtime, as well as extending the overall lifespan of the equipment. By having spare parts quickly available, companies reduce the impact of equipment failures, reduce the cost of repair and minimize the risk of extended downtime (Antosz & Ratnayake, 2019)

Efficient spare part management is a crucial aspect of equipment maintenance and repair. This includes accurate inventory management, timely procurement and delivery of parts, and effective tracking of parts usage. Additionally, effective spare parts management helps to reduce costs by ensuring that the right parts are available when needed while reducing excess inventory (Antosz & Ratnayake, 2019).

There are several factors that can affect the availability and cost of spare parts. For example, the age and popularity of the equipment can impact the availability of parts, as older equipment may have fewer parts available or may require custom-made parts. In addition, changes in manufacturing processes or materials can impact the availability of parts, as well as the cost of the parts themselves. For this reason, companies should pay attention to their spare part management (Hwang & Samat, 2019).

Primary products are distinct from spare parts in a way that they were initially sold to a client by the business. When a component or a part of the sold product malfunctions, spare parts are needed. So, the purpose of spare parts is solely to maintain or restore the primary goods' functionality and operability. In other words, spare components are only needed after the consumer has purchased the main items (Hwang & Samat, 2019).

The after-sales industry needs to be extremely adaptable since spare parts demand is driven by sporadic equipment breakdowns and human involvement. No matter how intelligent the people planning the demand, it is still a process of future projection with unavoidable difficulties and uncertainties (Antosz & Ratnayake, 2019; Hwang & Samat, 2019).

3.1.2 Special qualities of spare part business

As mentioned, the spare part business is a crucial aspect of the manufacturing and service industry. It involves the manufacturing, distribution, and sale of spare parts, components, and accessories that are necessary for the functioning of machines, equipment, and vehicles. The spare part business has unique qualities that set it apart from other industries, including its reliance on aftermarket sales, its complexity, and its global nature (Hu et al., 2018).

One of the unique qualities of the spare part business is its reliance on aftermarket sales. Aftermarket sales refer to the sale of spare parts and accessories to customers after the initial sale of a product. According to Durugbo (2019), aftermarket sales account for 25% of the revenue of many companies in the manufacturing industry, and in some cases, they account for up to 50% of a company's profits. Meaning that the spare part business is a significant source of revenue and profit for many companies, and it requires a specialized focus on customer service and support (Durugbo, 2019)

Another quality of the spare part business is its complexity. The spare part business involves managing an extensive inventory of parts, tracking demand and supply, and managing a complex supply chain. According to Antosz & Ratnayake (2019), spare part inventory management is one of the most challenging aspects of the spare part business, and companies that can effectively manage their inventory can significantly reduce costs and improve their customer satisfaction.

Finally, the spare part business is a global industry, with suppliers, manufacturers, and customers located all around the world. This global nature of the spare part business presents unique challenges, including managing currency risk, navigating different regulations and laws, and managing cultural differences. However, it also presents opportunities for growth and expansion, as companies can tap into new markets and expand their customer base (Hu et al., 2018).

In conclusion, the spare part business is a crucial aspect of the manufacturing and service industry, with unique qualities that set it apart from other industries. Its reliance on aftermarket sales, complexity and global nature makes it a challenging but rewarding industry to operate in. By effectively managing inventory, focusing on customer service, and navigating the challenges of the global marketplace, companies can successfully operate in the spare part business and achieve more growth and profitability (Hu et al., 2018).

3.1.3 Spare parts inventory management

Spare part inventory management is a critical aspect of operations management for many businesses. It involves planning, procuring, storing, and distributing spare parts that are needed for equipment maintenance, repair, and replacement. Effective spare part inventory management is vital for minimizing downtime and maximizing operational efficiency in companies. However, it has its challenges and opportunities (Zhu et al., 2020)

One of the most significant challenges in spare part inventory management is forecasting demand. Unlike finished products, the demand for spare parts can be highly unpredictable, making it challenging to determine the correct inventory levels. A research conducted by Pinçe et al. (2021), found that companies often rely on historical data and intuition rather than statistical models to forecast demand for spare parts, leading to inaccurate inventory levels.

The lead time required to procure spare parts can also vary significantly, depending on the supplier and the location. This can lead to delays in equipment repair and maintenance, resulting in extended downtime and reduced operational efficiency. Companies need to balance the cost of holding inventory against the potential cost of downtime if a critical spare part is not available. Storage is another significant challenge in spare part inventory management. Spare parts can take up a lot of space, and companies need to ensure that they have suitable facilities to store and organize them (Hu et al., 2018).

However, advanced technology has made it possible to automate many aspects of spare part inventory management. For example, predictive maintenance systems can aid companies to identify when a piece of equipment is likely to fail, allowing them to order the necessary spare parts in advance. Collaboration between suppliers and customers can also provide opportunities for improving spare part inventory management. By sharing information about demand and lead times, suppliers can ensure that they have the necessary inventory levels to meet their customers' needs. Data analysis can provide insights into demand patterns, allowing companies to make more accurate forecasts to optimize their inventory levels (Plinere & Borisov, 2015).

Outsourcing spare part inventory management can also provide opportunities for companies to reduce costs and improve efficiency. By outsourcing the spare part inventory management to a third-party logistics provider, companies can take advantage of their expertise in managing inventory and distribution (Skärberg, 2019).

Effective spare part inventory management is essential for ensuring that equipment is maintained and repaired quickly and efficiently. While there are many challenges in managing spare part inventory, there are also many opportunities for efficiency improvement and cost reduction. By leveraging technology, collaboration, data analysis and outsourcing, companies can overcome the challenges and utilize opportunities presented by spare part inventory management (Zhu et al., 2020).

3.2 Industrial service business environment

Industrial services refer to a wide range of activities and processes that support the manufacturing and production of goods, including maintenance, repair, installation and upgrading of equipment and facilities. These services are critical to the efficient and safe operation of industrial facilities and have been the subject of numerous studies and research (Kowalkowski et al., 2017).

One of the key areas of industrial services is maintenance, which involves the regular inspection and upkeep of equipment and machinery to ensure their optimal functioning.

According to a study by Selcuk (2017), effective maintenance practices improve equipment reliability, reduce downtime, increase productivity and minimize the risk of equipment failure in industrial facilities. Another important aspect of industrial services is repair, which involves the timely and efficient resolution of equipment malfunctions or breakdowns. Repair services and maintenance activities can improve the overall equipment performance (Selcuk, 2017).

Installation and upgrading of equipment and facilities are also critical industrial services. According to Antosz & Ratnayake (2019), effective planning and execution of installation projects can significantly reduce project lead time, minimize costs and improve customer satisfaction. The industrial service business environment refers to the complex set of factors and conditions that shape the operations and performance of firms that provide specialized services to industrial clients (Kowalkowski et al., 2017). These firms typically offer customized services and solutions that help their clients optimize their operations, reduce costs, improve efficiency, and enhance their competitiveness in their respective markets. This environment is characterized by a range of challenges and opportunities that affect the strategies, processes, and outcomes of these firms (Kowalkowski et al., 2017).

One of the key challenges facing industrial service providers is the increasing competition in their markets. With the globalization of the economy and the rise of digital technologies, firms are facing intense competition from both domestic and international competitors. This has led to a growing emphasis on innovation and differentiation as key drivers of success in the industry (Kowalkowski et al., 2017). According to a study by Kohtamaki et al., (2015), industrial service providers must focus on creating value through innovation, enhancing customer experience, and improving operational efficiency in order to compete effectively in this environment.

Another major challenge industrial service providers are facing is the need to adapt to changing customer demands and expectations. As industrial clients become more demanding, service providers must be able to respond by offering more customized solutions that are tailored to their customers' specific needs. In order to companies to be able to satisfy these customer needs, they need to have a thorough understanding of the client's business and operations, as well as the ability to offer flexible and adaptable solutions. Kohtamaki et al., (2015), highlights the importance of customer-centricity in the industrial services industry, noting that service providers must focus on delivering superior customer experiences in order to build more long-term relationships with their clients (Kohtamaki et al., 2015).

In addition to these challenges, the industrial service business environment is also shaped by a range of technological and regulatory factors. Technological innovations, such as the Internet of Things (IoT) or artificial intelligence (AI), are driving rapid change in the industry and are creating new opportunities for service providers to offer innovative solutions. However, these advancements also require significant investments in technology and expertise, which can be a major barrier to entry for smaller firms (Yarlagadda, 2018). Similarly, regulatory changes in areas such as environmental compliance and data privacy are also shaping the business environment for industrial service providers (Schäfer et al., 2022).

Despite these challenges, there are also many opportunities in the industrial services industry. One of the key opportunities is the growing demand for sustainable solutions that reduce environmental impact and promote social responsibility (Hu et al., 2018). According to Hu et al. (2018), sustainability is becoming a key driver of growth and profitability for industrial service providers, as clients increasingly seek out partners that share their commitment to sustainability (Hu et al., 2018).

Another opportunity for firms in the industrial services industry is the growing trend towards outsourcing of non-core functions by industrial clients. As companies seek to focus on their core competencies, they are turning to service providers to handle a range of functions, from maintenance and repair to logistics and supply chain management.

This trend is creating new opportunities for service providers to expand their offerings and increase their revenue streams (Dudė et al., 2021).

In conclusion, the industrial service business environment is a compound and rapidly changing landscape that presents both challenges and opportunities. To succeed in this environment, service providers must focus on creating value by adapting to increasing customer demands and expectations. By leveraging technological advancements and responding to regulatory changes, firms can capitalize on the opportunities presented by this dynamic industry (Hu et al., 2018).

3.3 Customer service

In today's highly competitive market, businesses need to stand out from their competitors. One way of creating a competitive advantage is providing excellent customer service, since customer retention is essential to the success of any business. In general, it is much easier and more cost-effective to preserve existing customer relationships than it is to obtain new ones. Customer relations can only be built through high-quality customer service, which makes it vital to the success of any company (Musumali, 2019).

Although customer service is crucial for any business, it is important especially for spare part businesses. In such business, customers rely heavily on knowledgeable and responsive service to find the exact spare part they need. Customers seeking for spare parts expect the business to provide them with correct information and high quality service, making the customer experience key factor in the business. A reliable service will help gain the customers trust, which can often lead to long-term partnerships and positive word-of-mouth referrals (Musumali, 2019).

As mentioned previously, the timely delivery of spare parts is essential for customer satisfaction in the spare part business. Therefore, understanding customer needs and meeting their expectations is critical for success in this industry. In order to take customer needs into account, businesses must first identify and understand their customers' specific requirements. This involves understanding of different industries and their unique operational needs. This understanding can be achieved through customer surveys, market research, and customer engagement (Camilleri, 2018).

Once customer needs are identified, businesses can use this information to design and implement strategies for meeting those needs. For example, a business may need to offer faster delivery times, provide real-time updates on the status of an order, or develop customized solutions to meet a customer's unique requirements. Additionally, businesses should invest in customer service and support, ensuring that customers have easy access to information and assistance when they need it. By taking customer needs into account, businesses will not only improve customer satisfaction but also gain a significant competitive advantage in the market (Camilleri, 2018).

The main goal in customer service is creating customer loyalty and building a good image. Building a loyal customer base not only helps generate repeat business but also contributes to increased profitability, improved reputation, and long-term sustainability. One of the key advantages of customer loyalty, especially in the spare parts business, is the potential for recurring revenue. Additionally, it can reduce the cost of customer acquisition, as loyal customers can act as advocates and refer others to the business (Musumali, 2019).

Moreover, customer loyalty also plays a crucial role in enhancing a business's reputation. Satisfied customers tend to share their positive feedback with others, which can increase brand awareness and lead to a larger customer base. In contrast, unhappy customers can damage a business's reputation through negative reviews and word-of-mouth. Thus, offering an excellent customer service can help improve a business's overall image and credibility (Musumali, 2019).

Furthermore, customer loyalty is also essential for long-term sustainability. The spare parts business is highly competitive and maintaining a loyal customer base can help a business withstand market fluctuations and changes in consumer behavior. Loyal customers are more likely to stick with a business even when faced with challenges such as price increases, changes in product offerings or supply chain disruptions (Musumali, 2019).

The quality of the customer service is key to customer loyalty that is critical for success in the spare parts business. Building a loyal customer base can lead to recurring revenue, improved reputation, and long-term sustainability. Therefore, businesses in this industry should prioritize customer satisfaction and work towards building stronger relationships with their customers.

3.4 Lead time management

Lead time management is the process of arranging and controlling the time between the initiation and completion of an order or project. In other words, it is the amount of time between receiving an order and delivering the finished product to the customer. The lead time includes all the steps involved in the production process, such as design, procurement of materials, manufacturing and shipping. The goal of lead time management is to minimize the time it takes to complete a project or an order while maintaining quality and maximizing efficiency (Mamani & Moinzadeh, 2014).

Lead time management is important for several reasons. It can assist businesses improve their customer service by delivering products or services to customers faster. In today's fast-paced environment, customers expect quick and efficient service (Mamani & Moinzadeh, 2014). By managing lead time, businesses can meet customer expectations and improve their customer loyalty. Properly executed lead time management can also benefit businesses by reducing costs. Shorter lead times mean that businesses can reduce the amount of inventory they need to carry, which can result in lower storage and handling costs. Additionally, reducing lead times can also assist businesses to improve production efficiency and reduce waste, which can result in lower costs overall. Therefore, effective lead time management can help businesses become more agile and responsive to changes in demand (Mamani & Moinzadeh, 2014).

Despite the benefits of lead time management, there are also several challenges associated with it. One of the main challenges is the complexity of the production process. Managing lead times requires coordination and communication between different departments and suppliers, which can be difficult in complex supply chains. Additionally, unexpected delays or disruptions in the production process can increase lead times and result in missed delivery deadlines (Mamani & Moinzadeh, 2014). Another challenge is the cost associated with reducing lead times. Shortening lead times may require additional investments in technology, equipment and training. These costs can be significant, especially for small and medium-sized businesses with limited resources (Mamani & Moinzadeh, 2014).

To overcome these challenges, businesses can implement various strategies to manage their lead times more effectively. These strategies include improving communication and collaboration between departments and suppliers, investing in new technology and automation to streamline production processes and adopting lean manufacturing principles to decrease waste and further improve efficiency (Mamani & Moinzadeh, 2014).

The spare part business is highly time-critical because the failure of a critical part can cause extensive downtime and significant financial losses for businesses. The availability of spare parts in a timely manner is crucial to ensure the continuous operation of equipment and machinery. Delays in obtaining spare parts can lead to longer lead times, which can result in production downtime, reduced efficiency, and lost revenue (Antosz & Ratnayake, 2019, p. 212-225).

Several studies have investigated the impact of lead time management on the time-criticalness of the spare part business. According to Antosz & Ratnayake (2019, p. 212-225), effective lead time management can significantly reduce lead times, improve service levels and increase customer satisfaction. The study found that by using predictive analytics and demand forecasting, businesses can optimize inventory levels and reduce the time it takes to procure and deliver spare parts.

Chang & Lin (2018) investigated the effect of supply chain resilience and visibility on lead time management in the spare part business. They found that by improving supply chain resilience and visibility, businesses can better manage lead times and diminish the risk of stockouts. The study also highlighted the importance of supplier relationships in lead time management.

Lead time management is an important aspect of business operations that can help businesses improve customer service, reduce costs, and become more agile and aware of changes in demand. While there are challenges associated with managing lead times, businesses can overcome these challenges by implementing effective strategies and investing in the necessary resources. Studies have shown that effective lead time management can improve service levels, increase customer satisfaction, and reduce the risk of stockouts.

3.4.1 Time-based competition

In the spare parts business, time-based competition refers to the company's ability to provide products or services faster than its competitors. The faster a company can provide the necessary parts to their customers, the better their time-based competition will be (Sapkauskiene & Leitoniene, 2010). This is particularly important in spare part industry where customers downtime can lead to significant losses, such as manufacturing, transportation, and power generation (Antosz & Ratnayake, 2019, p. 212-225).

According to Leseure (2010), time-based competition is a critical factor for companies operating in the service business. Leseure (2010) highlights the importance of having an efficient supply chain, since it reduces lead times and improves delivery times to customers. Additionally, Leseure (2010) suggests that the use of technology can help companies optimize their supply chain and improve their time-based competition. Leseure (2010) found that time-based competition can create a key competitive advantage for companies in various industries, including the spare parts business. Leseure (2010) also claims that companies that can deliver products and services faster than their competitors enjoy higher customer satisfaction rates and are more likely to retain their customers.

As mentioned, companies can invest in technology in order to improve their time-based competition. This includes technologies such as predictive maintenance and real-time tracking of spare parts inventory. With these investments companies can anticipate the need for spare parts and ensure that they are available when required, reducing lead times and improving delivery times to customers (Leseure, 2010).

In summary, time-based competition is an essential aspect of the spare parts business, as faster delivery times will lead to improved customer satisfaction and customer engagement. Efficient supply chain management and the use of technology can help companies optimize their operations and improve their time-based competition. Overall, the spare part business is a competitive industry and the time-based competition plays a significant role in succeeding in the business.

3.4.2 On-Time-Delivery

On-Time-Delivery (OTD) refers to a company´s ability to deliver products or services to the customer within the promised timeframe. OTD is crucial for the success of any business, as it directly impacts customer satisfaction, brand reputation, and business profitability (Dündar & Öztürk, 2020).

OTD is a key performance indicator (KPI) used to measure a company's efficiency and effectiveness (Bhatti et al., 2014). It is a metric that should be closely monitored by both the company and the customer. Companies that can consistently meet their OTD targets will build a reputation for reliability, which can lead to repeat business and customer loyalty. On the other hand, failure to meet OTD targets can lead to customer dissatisfaction, loss of business, and damage to the company's reputation (Dündar & Öztürk, 2020).

The importance of OTD is even more crucial in the spare part business (Dündar & Öztürk, 2020). Customers in the spare part business require quick access to spare parts to keep their equipment or machinery running. Equipment breakdowns can cause extensive production downtime, leading to lost revenue and increased costs in the customer's end. Therefore, the ability to deliver spare parts on time is critical for maintaining customer satisfaction and ensuring business continuity (Antosz & Ratnayake, 2019, p. 212-225).

OTD in the spare part business is closely linked to customer satisfaction and customer excellence (Dündar & Öztürk, 2020). Customer satisfaction refers to the degree to which a customer is satisfied with a company's products or services (Antosz & Ratnayake, 2019, p. 212-225). Customer excellence refers to a company's ability to consistently exceed customer expectations (Becker & Jaakkola, 2020). Companies that can deliver spare parts on time and that way create an image as a reliable supplier, usually have more loyal and satisfied customer base. Therefore, OTD is reasonable indicator for customer satisfaction and excellence in the spare part industry (Dündar & Öztürk, 2020).

3.5 Information system design

As mentioned in the beginning of this chapter the concept of ISD is introduced in detail since the main goal of this research is to improve an existing information system related process. ISD is the process of creating a blueprint for an information system that meets the needs of an organization. This involves designing the architecture, hardware, software, and communication infrastructure of the system. The goal of ISD is to produce a system that is efficient, reliable, and user friendly (Langer, 2007).

The design of an information system is closely linked to the concept of process improvement and development. Process improvement and development involve the analysis and improvement of business processes to increase efficiency, reduce costs, and improve quality. Information systems can be used to automate and further improve these processes. The design of the information system should take into account the current processes and identify areas for improvement (Langer, 2007).

One of the main benefits of ISD is that it can help to streamline business processes. By automating tasks and reducing the amount of manual work required, an information system can make processes more efficient and reduce the chance of errors. For example, an online ordering system can help to automate the ordering process, reducing the need for manually inserting data while preventing the chance of human errors (Langer, 2007).

Another benefit of ISD is that it can improve communication and collaboration within an organization. By creating a centralized system to store and share information, employees can work more effectively together. For example, a project management system can help to improve collaboration by allowing team members to share information, track progress in real-time and share tasks within the team (Langer, 2007).

Overall, ISD is an important process for any organization looking to improve their operations and increase productivity. By designing a system that meets the needs of the organization and considers current processes, an information system can help to automate tasks, reduce errors, and improve collaboration (Langer, 2007).

3.6 Process improvement and performance

Process improvement is a structured approach to analyzing, measuring and optimizing the processes that drive business operations. It involves identifying areas of inefficiency, reducing waste and errors, and streamlining workflows to improve overall efficiency and effectiveness (Malinova et al., 2022).

Process improvement is critical for service businesses because these organizations rely heavily on processes to deliver consistent, high-quality service to customers. Inefficient processes can result in delays, errors, and poor customer experiences, which can ultimately lead to lost business and damaged reputations. By improving processes, service businesses can enhance their ability to deliver quality service while reducing costs and improving customer satisfaction (Knofius et al., 2021). One of the primary benefits of process improvement is increased efficiency. By identifying and eliminating wasteful or unnecessary steps in a process, businesses can reduce the time, effort, and resources required to complete tasks. This can result in faster turnaround times, increased productivity, and improved profitability (Malinova et al., 2022).

Process improvement can also help service businesses identify opportunities to standardize their operations (Malinova et al., 2022). By establishing standard procedures for tasks such as onboarding new employees or handling customer complaints, businesses can reduce the risk of errors and ensure consistency in their service delivery. This can aid building trust and confidence with the customers (Knofius et al., 2021; Malinova et al., 2022).

Another benefit of process improvement is increased agility (Malinova et al., 2022). By continuously analyzing and optimizing their processes, businesses are able to adapt to the constantly changing economic environment and customer needs. This can help them stay ahead of competitors and respond more effectively to evolving business challenges. This also allows companies to customize their services to meet changing customer demands (Knofius et al., 2021; Malinova et al., 2022).

Finally, process improvement can help service businesses enhance their culture of continuous improvement. By motivating their employees to identify and propose improvements to the current processes, businesses can foster a culture of innovation and continuous learning. This can help employees feel more engaged and motivated, which can improve retention and overall organizational performance (Knofius et al., 2021; Malinova et al., 2022).

Process performance refers to the effectiveness and efficiency of business processes in achieving their intended outcomes. It is a measure of how well processes are designed, executed, and controlled and how well they support the overall goals of the organization. Process performance is important to companies, especially in the service industry, because it impacts customer satisfaction, operational efficiency and financial performance (Aydiner et al., 2019).

In the service industry, process performance is particularly important because service processes are often complex and involve multiple steps and interactions with customers (Jääskeläinen & Laihonen, 2014). Service companies must provide a seamless and satisfying customer experience while also managing costs and ensuring quality. Poor process performance can result in delays, errors, and poor customer experience. By focusing on process performance, service companies can identify and address issues in their processes, leading to faster service delivery, fewer errors and higher customer satisfaction. This can improve customer loyalty and retention, as well as generate positive word-of-mouth referrals and reviews (Jääskeläinen & Laihonen, 2014).

In addition, process performance can help service companies to innovate and differentiate themselves from competitors. By continually improving their process performance, service companies can offer new and innovative services, as well as provide existing services more efficiently and effectively. This can increase customer satisfaction and profitability (Jääskeläinen & Laihonen, 2014).

3.7 Data integration

One of the primary elements of the data management process is data integration. The procedure entails gathering and combining data from all sources into a solitary dataset or data warehouse. The main objective of data management is to satisfy the various requirements of all business applications and processes while granting users consistent access to and delivery of data (Wu et al., 2021).

In today's business environment, companies use multiple systems to manage their operations. This results in segregated data, making it hard to analyze and manage. Data integration is essential since it enables organizations to have a complete view of their data, while being able to reach all information needed for decision making and monitoring processes (Sherman, 2015).

In order to deliver comprehensive and reliable information, data integration helps manage all of these enormous databases. The management of company and consumer data is one of the most popular use cases for data integration. There are many obstacles to data integration in the world of today since there is so much data available. It is difficult enough to collect data from several sources and combine it into a single framework (Sherman, 2015).

3.8 Different methods of implementing data integration

Data integration can be implemented in many different ways (Wu et al., 2021). A simplified data integration model is illustrated in Figure 5. The following two data integration methods can be used to achieve the goal of delivering comprehensive and reliable information: ETL (Extract, Transform, Load) and ELT (Extract, Load, Transform). Since the data is collected from multiple sources and combined, the end user is able to make more calculated and smarter decisions based on more comprehensive and uniform data.

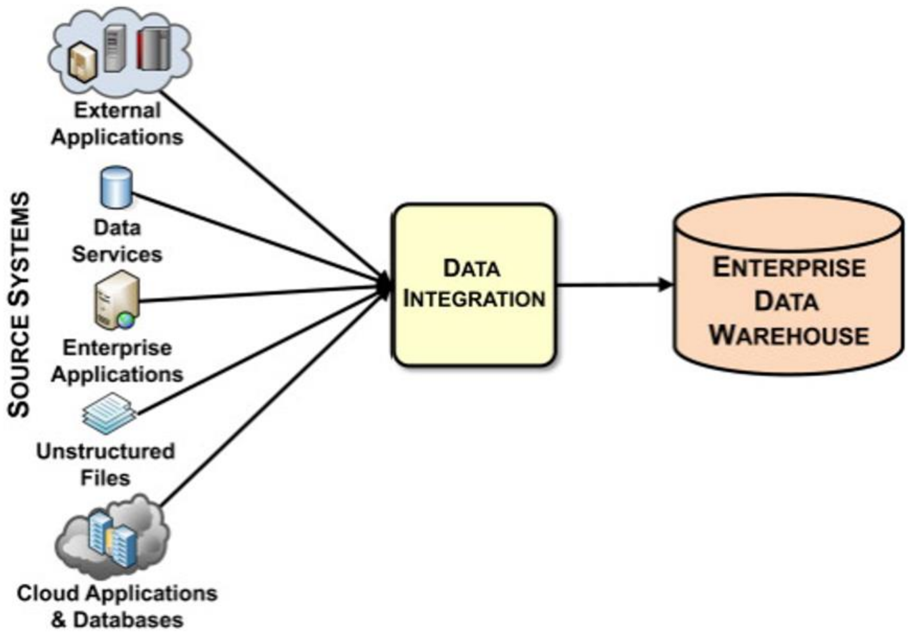

Figure 5. Simplified data integration model (Sherman, 2015).

Figure 6 illustrates the data integration process known as "extract, transform, and load", or ETL, which gathers data from the source systems and transfers it into the warehouse. (2015, Sherman). This process is continually carried out by data warehousing to transform a variety of data sources into consistent, relevant information for analytical operations and business intelligence (Sherman, 2015).

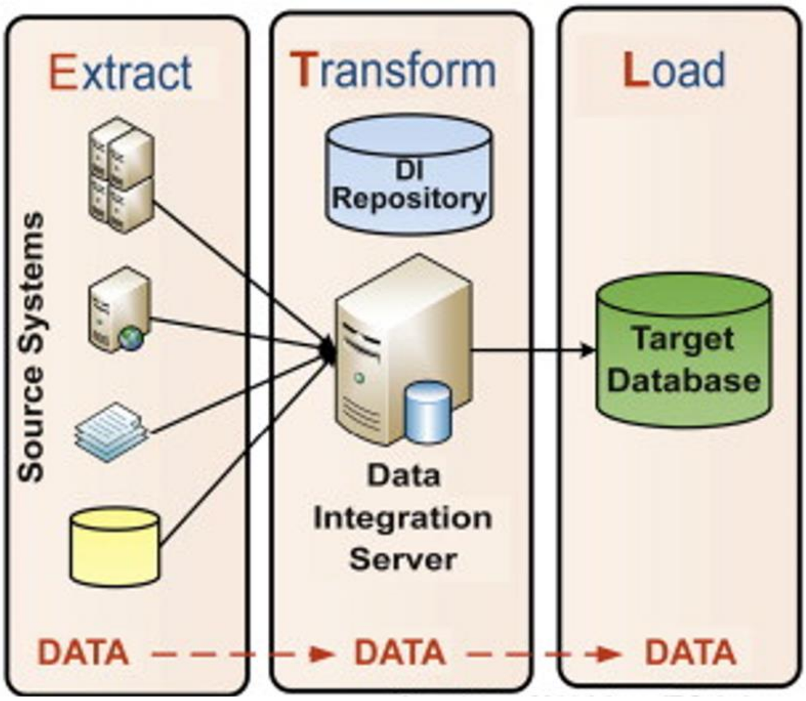

Figure 6. ETL architecture (Sherman, 2015).

During the Extract phase of the ETL process, data is taken out of several databases, text files, and application programming interfaces (APIs). During the Transform step, the data has to be cleaned, standardized, merged with other data sources, and run through any necessary calculations or transformations. During the load step, the transformed data is imported into the chosen database (Sherman, 2015).

ETL techniques are used to ensure that data is somewhat consistent, accurate, and up to date, while also making it easier for business users to locate and evaluate data from a variety of sources. Specialized ETL programs, which provide a range of tools and capabilities, are frequently used to extract, convert, and load data while executing ETL (Sherman, 2015).

The extract, load, and transform (ELT) data integration process transfers raw data from a source server to the data system of a destination server so that it may be processed for later use (Sherman, 2015). Figure 7 depicts a high level ELT procedure.

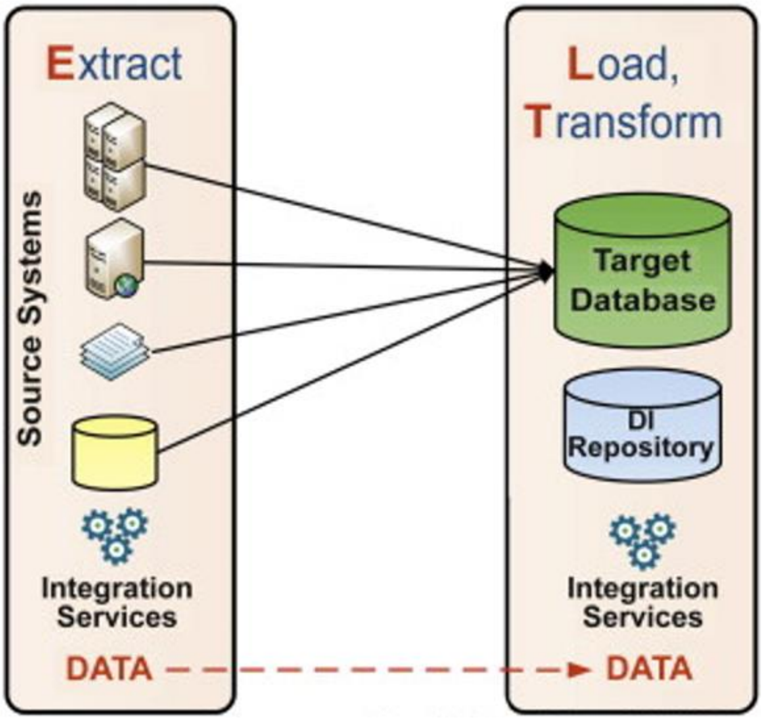

Figure 7. ELT architecture (Sherman, 2015).

Data extraction is the first step in the ELT process. Locating and accessing data from source systems, which might include CRM, ERP, files, databases, archives or any other trustworthy source of relevant information (Sherman, 2015). The procedure of loading the extracted data into the target database is the second step of ELT. In the last phase of the ELT, the data has to be converted. The process of converting data from its original format to the format needed for analysis is called data transformation. The basis of transformation is frequently a set of rules that outline how the data should be altered for usage and analysis in the targeted data storage. While there are many other techniques to transform data, lookup tables are typically used in this process to convert coded data into useable data (Sherman, 2015).

ELT is the most useful in the processing of large data volumes required for big data analytics and business intelligence (BI). ELT is more appropriate for nonrelational and raw data since the data is replicated "As-Is" from the original source. (Sherman, 2015). Beyond simply switching the L and the T, there are other significant differences between an ELT and a traditional ETL process. The primary factors are how, when and where data transformations are performed. The raw data is not available in the data warehouse as ETL alters the data before loading it. ELT entails transforming the stored data once it has been transformed and putting the raw data into the data warehouse.

Whatever the location of the data, data integration gives businesses a uniform picture of their information. They are better equipped to understand their operations and make well-informed judgments as a result. For example, a store may keep track of sales, inventory and customer information using several different systems. By integrating the data, the company can have a complete view of their business, such as the inventory they have on hand, the products that are selling well, and their most valuable customers. Data integration reduces the time and effort required to manage several systems, which increases operational efficiency. Because the procedure is automated, employees may concentrate on other important responsibilities, increasing productivity (Sherman, 2015).

In conclusion, data integration is essential in today's corporate world since businesses run their operations using a variety of technologies. It gives businesses a comprehensive picture of their data, empowers them to make wise decisions, boost productivity and spot untapped opportunities. Thus, in order to succeed, firms must invest in data integration technologies and strategies (Sherman, 2015).

3.8.1 Tools for supporting data integration

Data integration is a crucial component of business operations since it allows for smooth connectivity and communication between diverse systems, applications, and databases (Wu et al., 2021). OPENJSON and MuleSoft, for instance, are just two of the numerous technologies that are accessible and significantly improve effective data integration (Möller et al., 2021; Alphonse et al., 2022).

During the interviews with chosen stakeholders in VFC, it became apparent that OPENJSON and MuleSoft solutions are used within the company in various data integrations. Since the databases are in Microsoft SQL ecosystem, the two solutions are used individually and together depending on the scope of the integration. OPENJSON and MuleSoft solutions will be reviewed in more detail since the use of these solutions has started to increase within the company in automated data warehouse integrations.

One crucial integrated component of the Microsoft SQL Server environment is OPENJSON. It easily integrates JSON-formatted data into relational structures and facilitates its parsing. OPENJSON makes relational data warehouses compatible with JSON, a lightweight data exchange format that is often used for web-based data transfer (Möller et al., 2021; Alphonse et al., 2022). OPENJSON promotes compatibility with current relational data warehouses by making it simple for developers to import JSON data into SQL Server tables or include it in queries. One of OPENJSON's unique advantages is that it integrates naturally with SQL Server (Möller et al., 2021; Alphonse et al., 2022).

MuleSoft functions as a comprehensive integration platform that connects many services, applications, and data sources, irrespective of the underlying technology. MuleSoft is versatile for merging on-premises and cloud-based apps since it provides a large selection of connectors and protocols (Alphonse et al., 2022). One noteworthy feature of MuleSoft that allows businesses to create connections with several phases and conditional logic is its ability to manage complicated workflows. When data needs to go through certain processes or modifications, this capability is quite helpful (Alphonse et al., 2022).

OPENJSON is very useful in SQL Server settings since it provides effective JSON parsing and integration features. MuleSoft, on the other hand, serves businesses with a variety of intricate integration needs thanks to its extensive integration platform (Möller et al., 2021; Alphonse et al., 2022). A number of considerations should be taken into account when implementing these solutions, including the complexity of integration workflows, the long-term integration plan, scalability requirements, and the current infrastructure (Möller et al., 2021; Alphonse et al., 2022).

4 METHODOLOGY

Choosing the correct method for scientific or practical research is pivotal for various reasons. It minimizes subjectivity and biases that could affect the accuracy and dependability of the results by ensuring a methodical and impartial approach. In order to guarantee the authenticity and trustworthiness of the data gathered and lay the groundwork for deriving significant findings, a strong research methodology is essential (Blair, 2016)

This chapter will go through the methods and the research process used in this study. The nature of the problem has led to the decision to use design science research (DSR) approach as the method to conduct the research and form the structure of the thesis. The model for design science research methodology (DSRM) structure is illustrated in Figure 8. In addition to DSRM, tools from other research methods are incorporated in this research in data analysis and in the design and development. Multiple iterations must be done to ensure the functionality of the created artifact(s) in the research (Brocke et al., 2020).

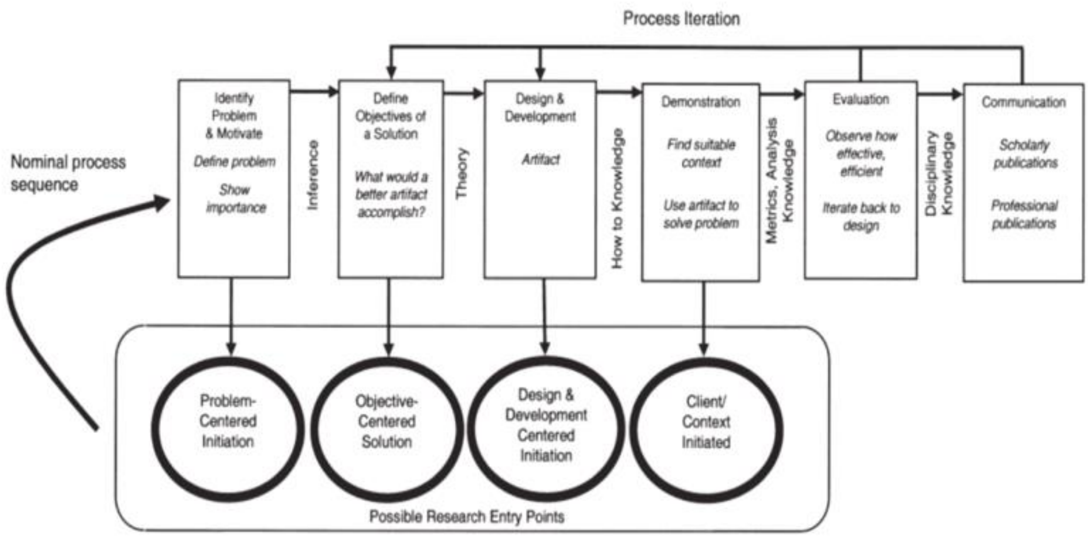

Figure 8. DSRM process model (Brocke et al., 2020).

4.1 Research methodology

This research follows the DSR approach due to the normative nature of the research problem and the need for process improvement. The choice of this approach stems from the author's direct involvement with the organization. The primary objective of the research is to construct a technical solution that effectively addresses the presented problem. In addition, analysis tools and aspects from information system design (ISD) and business process re-engineering (BPR) methods have been incorporated to the DSR approach. Fundamentally design science research approach aims to improve an existing process. This approach provides immediate value to the company by proposing a technical solution (Brocke et al., 2020).

Combining these research methods make it possible to analyze current practices, benchmark other organizations and propose improvements. Process analysis tools such As-Is, To-Be and other process flow diagrams are in the center of this research. With the use of these tools, the structure of the processes including the different steps and key decision-points for the automation of spare part lead times are portrayed.

Design science is a research approach which aims to develop solutions for practical engineering problems (Brocke et al., 2020). The conceptual framework of DSR is illustrated in Figure 8 (see p. 45). DSR framework aids in implementing and assessing DSR method used in the study. Although the research has been conducted using the DSR approach, other tools from information system design (ISD) and business process re-engineering (BPR) have been incorporated in the data analysis. Data collected from interviews, benchmark at Wärtsilä spare part facility and the actual lead time data have been analyzed using the mentioned tools to create the automation logic for updating spare part lead times and the data integration between two data warehouses.

In DSR methodology, an artifact refers to a construct, model, method, system or other technology-based solution that is created to address a specific problem or opportunity (Brocke et al., 2020). The artifact is the primary outcome of the research process and is designed to improve the performance of a specific task or process. Artifacts can take many forms, for example software systems, databases and other technology-based tools. The artifacts are typically designed and developed iteratively, with each iteration informed by feedback from users and stakeholders (Brocke et al., 2020).

In DSR the artifacts are evaluated using a set of criteria that are established at the research process. These criteria typically include:

- the artifact(s) ability to solve the research problem
- the artifact´s ability to save time and reduce costs
- the artifact’s usefulness to company and its stakeholders
- and the quality of the artifact(s) in terms of its technical and design features (Brocke et al., 2020).

The use of artifacts in design science research methodology is based on the premise that the creation of new technologies can lead to new knowledge, and that this knowledge can be used to improve the performance of specific tasks or processes (Brocke et al., 2020). The artifacts created through design science research can have practical applications in different industries (Brocke et al., 2020).

4.2 Data collection

For the foundation of this research different data was collected to better understand the As-Is process for the spare part lead time update and the issues within the process. The data was collected in several different ways including:

- Interviews
- Benchmark
- Spare part lead times
- Spare parts items

Interviews were conducted as semi-structured interviews to gain a comprehensive understanding of the requirements for a new spare part lead time update procedure and the implementation of data integration. This type of interview was selected since it can incorporate theoretical inquiries as well as create an opportunity for more discussion (Kallio et al., 2016). The interview question can be found in Appendix 3.

The interviews were conducted with a spare part product manager, five selected IT managers and a data architect since there are two aspects of this research. First is to create the automatic logic to calculate spare part lead times based on the available data in M3. Secondly to create a data integration between M3 and CPQ data warehouses. This small group of people, who have skills essential to the implementation of the work, were selected to be interviewed.

Spare part product manager and two of the five selected IT managers were interviewed regarding the calculation logic and the use of the available lead time data in M3. The other three IT managers and the data architect were interviewed in order to understand the current data integration practices within in the company and how the integration can be built between the data warehouses. With the help of these interviewees, an overall picture of what needs to be done and what the situation is like at the moment was created. The number of interviewees was kept small because only these people are responsible for spare part item data management, internal systems and their maintenance.

The researcher arranged a benchmark with a Finnish company that has large-scale global spare part operations. The agenda for the benchmark was to collect data and information about their spare parts operations to better understand the effects of the environment to lead times. The cause and effect relationship between lead times, OTD and customer satisfaction were also discussed. Essentially the benchmark gave reassurance for the scientific motivation behind this research.

In addition to the interviews and the benchmark existing spare part lead time and item data were gathered. Data was collected to understand how the As-Is spare part lead time update process is executed. Through this data collection method, the scope of the research was narrowed down. Consequently, from the data collected, the exact parts of the process that needed improvement, were pinpointed.

4.3 Data analysis

The data collected was analyzed to better understand the current spare part lead time update process and the difficulties surrounding it. The data analysis is used to answer the research questions in order to solve the research problem stated in chapter 2.1.

The As-Is spare part lead time update process was mapped based on the interview with the spare part product manager (Figure 3. p.16). Through deeper understanding of the current process, it was evident that the issues concerning the lack of automation needed to be discussed with the selected IT managers and data architect. These interviews provided an adequate basis for developing the As-Is process flow chart.

When examining the spare part item data in M3 and CPQ, it was apparent that the spare part lead times were not up to date. The reason being lack of proper ownership taken at spare part product management. This lead to other tasks being prioritized. When the purchasing or manufacturing lead time changes in the supplying warehouse, the information is not passed on to the Vantaa spare part warehouse (FFA). In addition, closer inspection revealed that certain types of spare part items were never updated to FFA. Also, certain factors affecting the spare part lead times were not taken into account in the existing calculation.

In conclusion, the interviews and the collected spare part lead time and item data helped to identify parts of the process that needed development. Based on data analysis, it was easier to start building the new calculation logic for the spare part lead times and the data integration for these lead times to be updated to FFA in M3 and to the CPQ. The data integration of the two data warehouses would ensure that the latest supplying warehouse item lead times would be used in the calculation.

After reviewing the spare part item data in the M3 data warehouse, it was possible to limit the amount of data needed for the integration to a minimum. When the amount of data to be transferred is relatively small, the data integration becomes more efficient. Also, closer inspection of the data warehouses implicated that the DW 1 was not suitable for the data integration because of performance related issues. This performance problem has been known for a while and new integrations are guided to use new DW 3 data warehouse. DW 3 has all the same raw data that DW 1 has and it is not over utilized.

5 RESULTS

This chapter presents the design and development of the two artefacts created in this research. These artefacts are the new automated calculation logic and the data integration. These artefacts together form the new automated lead time update process. Additionally, this chapter presents a demonstration of how the created artifacts provide an answer for the research questions and the research problem. The As-Is process (Figure 3. p.16) is presented in chapter 2.2. This figure along with the simplified quotation process flowchart (Figure 2. p.15) describes the current state of the process and where problems are encountered.

The new calculation logic and the data integration were implemented in cooperation by VFC`s IT department and data architect. This thesis was used as a basis for creating both mentioned artefacts. Researcher did all the planning, testing and correction suggestions for the artefacts.

5.1 Current calculation logic

Initial mapping of current calculation logic started with examining how current calculations were done in the lead time excels and what type of spare part items exists in M3 in FFA warehouse. Furthermore, open interviews with colleagues from various departments were conducted to find out if there are any synergies with other development projects in the company that could add value to this project. There were no on-going development projects that could any value to this project.

By mapping the current process, it was relatively easy to pinpoint the parts of the update process where development is needed. The spare part lead times calculated with the lead time excels were partly incorrect. For many items, the lead time excels did not simply work. For example, if the item had incomplete bill of material in M3. Also, the excel calculation could not take into account all the factors affecting the lead times. The excel calculation simply does not have any flexibility since the calculation logic is hard-coded. Meaning that the calculation does not know how to take exceptions into account when calculating lead times. This is the case, for example, with items that come as factory-to-factory (F2F) delivery from an overseas warehouse. The overseas warehouse has their own picking, packing and shipping times which are not documented in M3.

The logic behind the current calculation is presented in Appendix 4. There are three types of spare part items: purchase item (PO), distributed item (DO) and manufactured item (MO). These categories are then divided into subcategories illustrated in the second column. The third column describes the availability of the item and possible subcomponents. These three factors (columns 1-3) define the logic for calculating lead times. The calculation also takes into account buffers for possible machining delays and production planning. The calculated lead time is rounded up to a number dividable by five to unify the amount of items shipped per day. The rounding up aids in scheduling order picking, which then streamlines the spare part picking process.

5.2 Rework of calculation logic

After pinpointing the flaws in the original calculation logic, it was clear what needed to be done in order to include all spare part items into the updated spare part lead time calculation logic. During the examination of the original calculation logic, it was concluded that calculations should be executed directly in Microsoft SQL environment, where the calculation can be fully automated thus making it more efficient. Consequently, the results of the automated calculation can be directly transferred to CPQ and with little effort the updated lead times can updated to M3 in FFA warehouse.

The reworked calculation is not hard-coded as it was before. Meaning that all the significant information such as transfer times, picking times, machining and other buffers are in a data warehouse table, that can be edited if there are changes in the future to these factors. These factors are entered as static times in the system but can be easily modified if there are changes to be made. This allows flexibility to the calculation.

For the calculation to be functional and efficient, certain restrictions must be set before the calculation can be executed. The first so-called conditions for the calculation are that the item must be enriched to the FFA warehouse in M3 and that the item must be in active status. Thus, making sure that only correctly enriched and actively sold items are calculated and updated to CPQ and M3. Additionally, the item must have existing price and lead time in CPQ to be included in the automation. This ensures that only items that are offered from FFA warehouse are updated. In the future, if items were to be included in the automation, the price and the lead time must be set manually for the first time. This manual step ensures that correct items are included in the mass update.

There are around 40 000 active spare part items enriched in the FFA warehouse. These 40 000 items cover the most commonly delivered spare parts for active products in VFC offering. These active spare part items form the scope for the initial calculation and the new calculation logic presented in Appendix 5. This logic was created based on the active items. The new calculation logic takes into account, for example, distributed items from other warehouses to FFA, possible painting times for single actuator parts, picking times in the supplying warehouse and the safety stock values. In addition, the transportation time between Vantaa factory warehouse and FFA was reduced from five days to two days.

The first run of the automated calculation revealed there are around 5 000 items that cannot be processed with the initial set conditions. Further investigation of these items revealed that there are multiple reasons why the calculation failed for the items. For instance, items have incomplete bill of material, the item is not active in the supplying warehouse or the supplier information is missing for the item in FFA or supplying warehouse. The results of the first run are shown in Table 1.

Table 1. Result of the initial calculation.

Comment	Count	%
NULL (items with no errors)	35273	86,97 %
Missing bill of material	622	1,53 %
Missing single item in bill of material	1136	2,80 %
Missing supplying warehouse info	49	0,12 %
Undefined supplier	225	0,55 %
Item quantity incorrect in the bill of material	123	0,30 %
Item is not active in supplying warehouse	3130	7,72 %
FFA items in active status	**40558**	**100,00 %**

Based on nature of the errors, there was no need to make changes to the calculation logic. These items need to be manually checked to see if the error is intentional. For example, some of the machined items have empty bill of materials, which enables the use of alternative materials in stock to machine the part. Lead time for the items with intentional error can be set manually using a manual override function, which was created for these specific items. If the lead time for the item is set using the override function, the item is not in the automatic calculation scope and the validity of the lead time must manually checked from time to time.

For some of the items the enrichment process to the M3 has been incomplete, which indicates that it is simply a human error. Most of the human errors occur in the supplying warehouse. These items are not in high demand and the information for these items will be fixed the next time the item is quoted. In addition, there are items that are not active in the supplying warehouse, but the item is active in FFA warehouse. If these items need to be quoted, usually the entire supply chain data for the item needs to be updated.

After the initial test run it was determined which items can be included in the automatic calculation. Now that the scope of the items included in the automatic lead time calculation is determined, the results from the calculation can be examined. Through the examination, changes can be made in order to get accurate static lead times for the spare part items.

The examination of the calculation results was done for randomly picked items from the 35 000 items included in the calculation. In every iteration roughly 300 items were selected randomly and the lead time for items were manually calculated and compared to the automatically calculated results. If there were differences between the manual and automatic calculation results, the cause of the difference was investigated and corrected to the automation logic. In total of 11 test iterations were conducted until the calculation logic was determined to be functional and ready to use.

5.3 Data integration between data warehouses

In order to improve the management of quoted spare part lead times, a functional data integration is a necessity. Now that the actual spare part lead time calculation is proven to be in working order, the actual base data and the calculated lead times have to be able to transfer automatically between data warehouses. Earlier presented extract, transform, and load, or ETL architecture is used as the data integration model in this thesis. Spare part data is gathered from one data warehouse then transformed and loaded to the destination data warehouse.

As mentioned earlier in the research (Figure 3. p.16) the M3 spare part item data was fetched from DW 1 to calculate spare part lead times in mass. Due to performance related issues, a data integration between DW 1 and DW 2 is not possible to establish. During the design phase of the data integration, it was decided that the integration would be built between DW 3 and DW 2. DW 3 is a relatively new data warehouse built to reduce the use of DW 1. DW 3 has all the same M3 raw data as DW 1 but is not overutilized. The use of DW 3 in the data integration ensures that the spare part lead time calculation works seamlessly and does not affect other functions within the data warehouse.

The created data integration process between DW 3 and DW 2 is illustrated below in Figure 9. The integration transfers spare part lead time data from DW 3 to DW 2. The amount of data can be immense which is why OPENJSON insert is used for better performance. As mentioned earlier OPENJSON is already used in various data integrations within the company, so adapting the use of it was highly promoted from IT department. Without OPENJSON insert the data transfer between the data warehouses would take around 3000 minutes. With the insert it takes roughly 15 minutes to transfer all the needed data for the calculation.

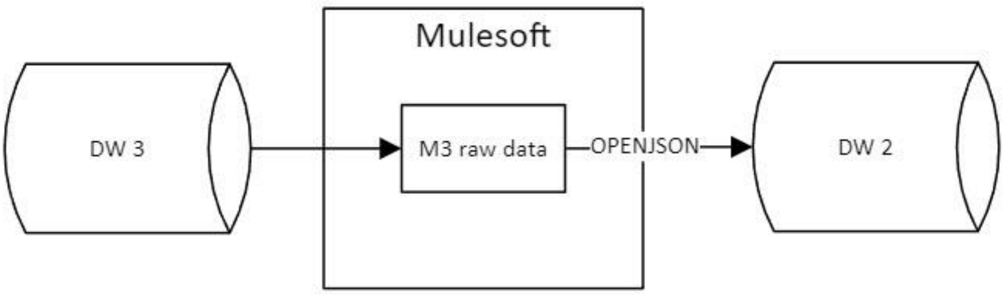

Figure 9. New data integration between DW 3 and DW 2.

After the data is transferred from DW 3 to DW 2, the new calculated spare part lead times must be inserted back to M3 and also to the sales tool CPQ. Below Figure 10 presents how the calculated lead time data is moved back to M3 and to CPQ. After the calculation in DW 2 is complete, only the delta items are transferred to M3 and CPQ. Since the CPQ data is stored in DW 2, there is no need for data integration. The new delta lead times will flow directly into CPQ. In order to transfer the delta lead times back to M3, an XML file needs to be created to insert the lead time values to M3. The XML is automatically sent from DW 2 to a share disk, from which the spare part lead time data is imported automatically to spare part warehouse in M3.

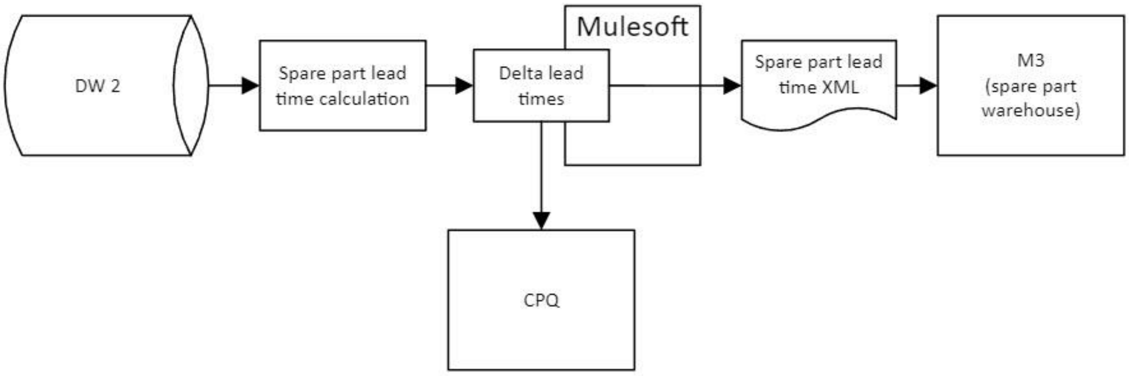

Figure 10. How newly calculated lead times are transferred to CPQ and back to M3.

If there is a delay or malfunction in the automated spare part lead time update process, the reason for the failure must be resolved within one week to ensure that there are no effects on the day-to-day business processes. Table 2. highlights the impact of the possible failure in the update process. No effect means that there is no effect to business. Low means that the failure causes minor troubles, but the business can continue. Medium means that the malfunction causes some problems and costs to business, but there is a manual workaround or other method that can be used instead. High indicates that the delay would cause lot of problems to business and generate high costs.

Table 2. The impact of the possible failure in the update process.

	Message delivery delay				
Criticality	1 min	1 h	1 day	2 days	5 days
High					
Medium					x
Low	x	x	x	x	
No effect					

If the delay of the data transfer takes less than five days, there are basically zero effects to the day-to-day business processes. When the delay is five days or more, the impact can be seen for example in quotation and sales processes. There are manual workaround options, if the delay would take more than five days, but it is unlikely that the problem would not be solved in one or two business days. Since the lead time update process is essential for business processes, an error message will be sent to the business and technical owners of the process, if there are failures in the automation. This ensures that the possible failures are noticed quickly and resolved as soon as possible.

5.4 New spare part lead time update process

Both created artefacts, the reworked calculation logic and the data integration between data warehouses, form the new spare part lead time update process. The new update process is illustrated in Figure 11.

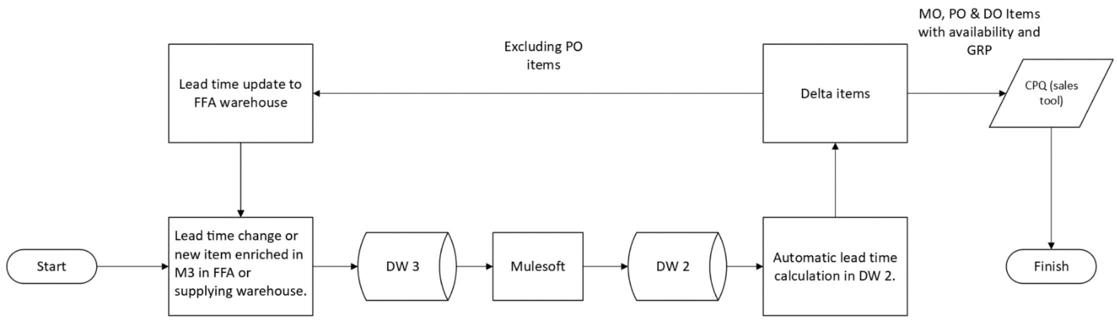

Figure 11. New spare part lead time update process.

Earlier the spare part lead time update was done once a year for the whole spare part category items. The old update process was slow, it did not update every active spare part item and it needed a lot of manual checking. The previous process was not effective enough for a business the size of VFC. The new spare part lead time update process calculates new lead times once a week and requires minimal amount of manual checking, making it effective and more useful.

The new update process starts every Friday morning 10.00 Finnish time. The amount of data that is transferred between the databases can be massive. The data is moved in chunks of 15 000 items to ensure the proper functionality of the process. Mulesoft integration keeps track of the moved items with a time stamp, which can be seen from a Power BI report (Appendix 6) created to monitor the update process. The time stamp helps keeping track of when and what values have been calculated for the item.

After the active spare part items are moved to DW 2, the calculation begins. When the calculation is finished for all of the spare part items, only for the items with a change (delta) in the lead time, the value will flow to M3 and CPQ. More specifically, spare part items labelled as manufactured or distributed items, will flow to M3. Purchased items are excluded from the M3 update, since factory purchasing team is responsible for updating these items. Items with existing global reference price (GRP) and lead time (availability) are updated to CPQ. This ensures that only items offered from Vantaa spare part warehouse are updated. This whole update process from start to finish takes two days. By Sunday evening the new spare part lead times are updated to M3 and CPQ.

By the time the first mass update with this new tool was made, the last update with the old update tool was done almost 18 months prior. About 90% of the "NULL" items in Table 1. were updated with this new update tool in the first automated update. The records of the calculations can be seen from the created Power BI log report. The report was created for monitoring the lead time update process. A screenshot of the created log report is presented in Appendix 6. In addition, a report for monitoring how the spare part lead times are developing was created. This report shows the averages of lead time changes for different types of items. A screenshot of this lead time development report can be seen in Appendix 7.

All in all, the design and development of this tool was executed successfully. The outcome was somewhat as expected, but the additional data from calculation results can be used to rectify the existing data, thus enlarging the scope of items included in the update process. By enlarging the scope of spare part items included in the lead time automation, more benefits will be brought towards other business processes within the company. For example, quotation engineers will receive less support requests (SR) from sales engineers regarding spare part lead times. The time spent solving the SR’s can be utilized in other tasks or development projects. In addition, the quoted spare part lead times are always up-to-date and consequently, it is less likely that there would be surprises regarding the lead time for the customer. This again improves the customer satisfaction.

6 DISCUSSIONS

The purpose of this thesis was to answer the below research problem:

How to optimally improve management of quoted spare part lead times in Valmet Flow Control`s service business line?

To achieve the objective of this thesis and to solve the research problem, the following research questions must be examined and answered:

1. What are the challenges in the current lead time update process in Valmet Flow Control?
2. How can data integration between ERP ja sales tool produces more reliable lead times?
3. What is the most optimal way to implement data integration between ERP and sales tool?

The first research question was answered in chapter 2.2 in form of a process flowchart model (As-Is process). The old lead time update process was very outdated, required substantial amount of manual work and in the end the tool could not calculate lead times for all spare part items. The old lead time update process was established before VFC had implemented Microsoft SQL environment into daily work of employees. Spare part lead times were calculated using hard-coded Excel update tools which did not allow any flexibility in the lead time calculations. This is the main reason why many of the spare part items were left out of the update scope. All of the above mentioned points made the process of keeping spare part lead times up to date very challenging.

The second research question was answered directly and indirectly throughout the thesis. In general, one of the primary data management elements is data integration. Combining data from different sources and gathering the collected data in one place makes the data management much more efficient. By creating a data integration bridge between DW 3 and DW 2 ensures that only the most recent spare part item data is used in the spare part lead time calculations. Data integration paired with an automatic spare part lead time calculation tool produces the most reliable static lead times. This has been tested and confirmed several times during the test and design phase of this thesis.

Third research question was answered in the results chapter. The process of creating a data integration was discussed with IT managers and data architect to ensure that the integration is built up to company`s standards and to make it as efficient as it can be. Also, the integration was built so that it does not interrupt other business process within the company using the same data warehouse for sourcing data. The integration between DW 3 and DW 2 was created using Mulesoft integration tool, which has been used in other integration projects company wide. To make the data transfer more efficient between the data warehouses, an OPENJSON insert is used for smooth and quick transfer. Mulesoft paired with OPENJSON makes the data integration efficient and optimal.

The research problem of the thesis was solved by reworking the old spare part lead time calculation logic and creating a data integration between the data warehouse, that stores the raw M3 data, and the data warehouse, that stores all the sales related data. Together these two created artefacts improve management of quoted spare part lead times. The integration enables the calculation to use up to date spare part lead times in the calculations. In addition, the tool recognizes those spare part items that cannot be automatically calculated and marks these items with a set error message. This ensures that all of the items not included in the automatic calculation can be corrected or the lead time can be set manually. Overall, the management of quoted spare part lead times can be managed with relative ease with this new calculation process.

The research method DSR paired with analysis tools and aspects from ISD and BPR incrementally helped to complete the work and to create the best possible technical solution that effectively addresses the presented problem. Fundamentally the aim was to rework an existing process.

Even though the tool works as it was designed, it is not perfect and it is not likely that this new update process will be the final one. As the processes, systems and supply chains change in the company the process must be able to adapt to the changes. Therefore, possible changes will likely happen in the future. Luckily, the tool is built in a way that the calculation logic is easy to modify if needed. The launch of this new update process received very positive feedback and it was something that had been expected for some time.

In conclusion, the update process is as good as it can be with the existing business processes and systems used in the company. Many people within the company have expressed that the tool has helped with their day-to-day activities. Quotations engineers receive less SR`s regarding outdated lead times and they can retrieve lead times in mass for large project quotations. Order confirmation team has received less customer feedback about the actual confirmed lead time for the orders, since the original quoted lead for the customer is correct.

7 CONCLUSIONS

Customers are expecting and demanding flexibility and excellent customer service in to-day`s fiercely competitive business environment. These points are even more emphasized in the spare part business were the need for spare parts tends to be unpredictable and erratic at times. Customers are expecting shorter and accurate lead times. Therefore, spare part supply chains are particularly challenging to oversee and manage. The above mentioned factors pressures companies to develop their business processes so that they are more responsive and have more visibility.

Obtaining the customer relations and keeping the customer satisfaction level high depends on having reliable supply of spare parts and service related activities. Interest towards this research arose from the need to enhance the customer satisfaction levels through quoting the customers reliable lead times. In addition, the need consisted of relieving the workload of certain teams in the spare part unit.

The purpose of this thesis was to automate the existing spare part lead time update process. Furthermore, this thesis is a foundation for future spare part lead time related development projects globally in VFC. This thesis also aimed to give more comprehensive information about the overall state of spare part items. For example, information about how many of the active spare part items in the spare part warehouse are actually active in the supplying warehouse or if there are any issues with the spare part data.

The research process started with understanding about how does the current spare part lead time update function. What factors are causing the need to update the business process and does the calculation work properly for all items in the update scope? After a thorough research of the existing process, information about business, customer satisfaction and data management were gathered to better understand the nature of spare part industry and data integration. Through this study, it was possible to determine, how to optimally improve the existing spare part lead time update process.

The theoretical chapter of thesis explains the special characteristics of spare part industry, the impact of customer satisfaction and the importance of data integration in data management. All in all, the purpose of the theoretical part of the thesis is to give a general understanding of spare part business and data integration, and how these two are connected in todays digitalized world and how these are critical in order to offer customers the best possible service. In addition, the theoretical section aims to give a scientific framework for the thesis.

After the theoretical framework was established, the processes of data collection and data analysis are presented. Data was collected in many ways and analyzed to form the basis for the new calculation logic and the data integration between two separate data warehouses. Data analysis revealed some technical issues with the current data warehouses, but the issues were solved with minimal effort. The data analysis provided more insight on how to best execute the design and development of the artefacts in order to develop the current spare part lead time update process.

Results chapter presents the design and development of the two artefacts that together form the new spare part lead time update process. The As-Is process was introduced in the very first chapters of the thesis, but the Integration model flowcharts and the To-Be flowchart were presented in the results chapter. The rework of the current calculation logic revealed that there were thousands of items that were not in the original spare part lead time update scope. In addition, the first result of the new calculation showed that there were close to 5 000 items that were having some data related issues in the supplying warehouse. The above mentioned findings helped to carve out the To-Be calculation logic. The results helped with understanding the data related issues that spare part items are facing and made it possible to fix those issues for the new tool.

The creation of the data integration between the two data warehouses did not oppose any major difficulties. The interviews with the IT managers and data architect were very informative so there were no unexpected surprises when the integration was created.

The integration was built using tools that are already utilized in other data warehouse integrations in the company. Basically, the outcome of the data integration was as expected.

In conclusion, the study was executed successfully due to comprehensive data collection and planning. The result of the thesis was a tool that gave a solution for the issues regarding the spare part lead time management process. One of the main challenges in the outdated spare part lead times in M3 and CPQ was lack of communication and data transfer between supplying warehouse and the spare part warehouse. The new spare part lead time update process not only serves the customer needs, but also reduces the amount of manual and unnecessary work within the company. This releases resources for more important tasks, resulting in cost savings.

7.1 Future research

This thesis will be the foundation for further development of spare part lead time management globally in VFC. The initial plan is to expand the use of this spare part lead time update model to two market areas. The expansion projects will start in the near future and the goal is to improve spare part lead time management throughout the company. The limitations set for this thesis will be the same in the upcoming expansion project. The goal is to produce the most accurate static lead times. This excludes the machining capacity and delays.

VFC has also launched a lead time reduction campaign. The aim is to reduce lead times by 30% in the next couple of years. The created spare part lead time calculation model is in the heart of this campaign. The lead times cannot be reduced unless the data management process is functional and the lead times are correct to begin with. When the foundation is in order and the lead time data is reliable, the company can make desired lead time related changes.

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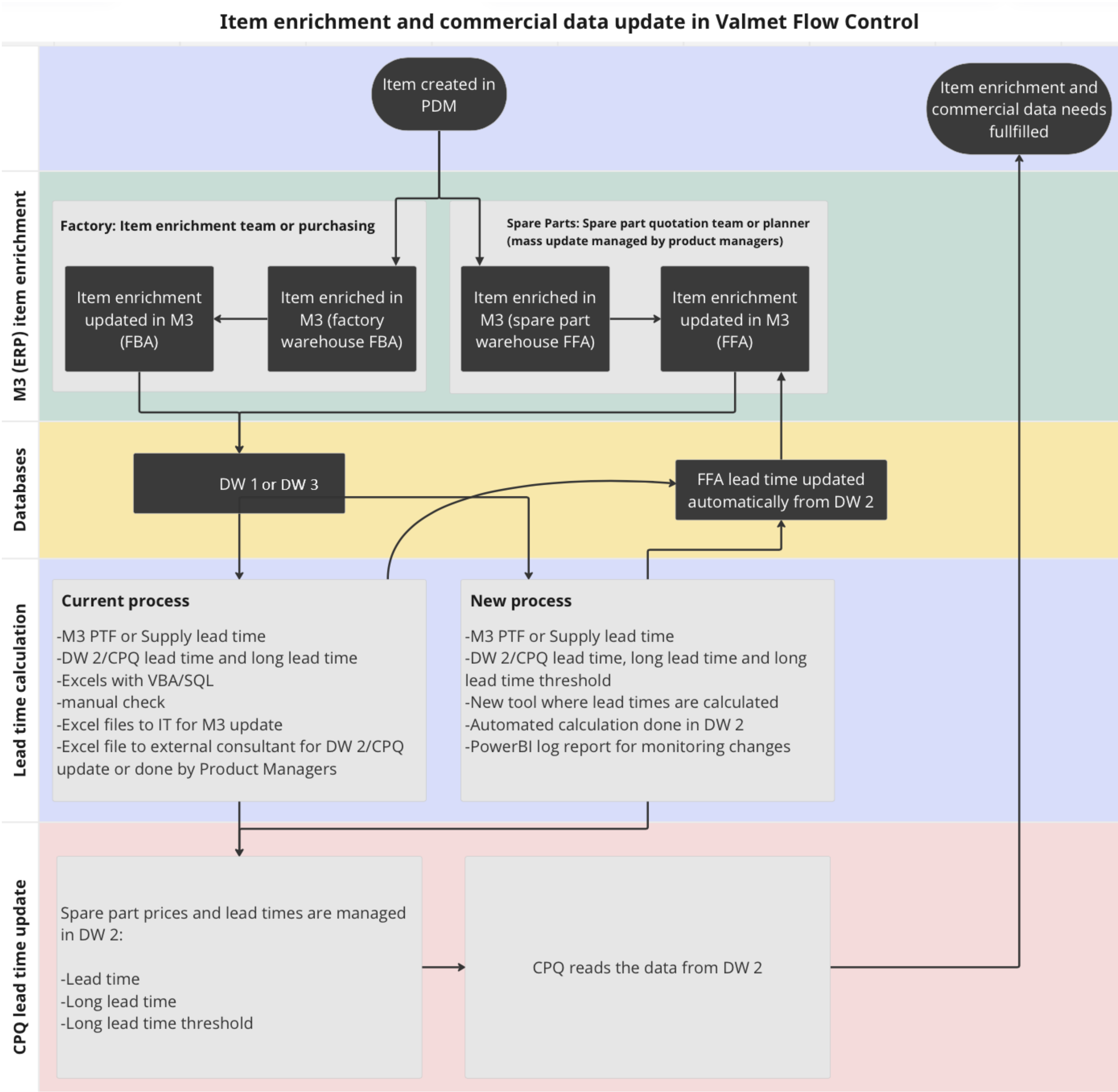
Appendices

Appendix 1. Main questions from Wärtsilä benchmark

Importance on lead time management and On-Time-Delivery (OTD)
How do you manage and maintain Wärtsilä`s global spare part operations?
Which spare part functions are automated and not automated?
Are the spare parts manufactured in-house or by a subcontractor?
Who plans the lead times for your spare parts?
How have your lead times changed in the last 3 years?
Have there been problems with the availability of components and raw materials? If so, how have they affected your lead times?
Have extended lead times caused problems for customers?

Appendix 2. Item enrichment and commercial data update



Appendix 3. Semi-structured interview questions

Spare Part Lead Time Management – Spare part product manager & two of the five IT managers
How are the spare part lead times updated currently?
How important is it for the company and the customer to have up to date lead times available?
Have there been problems with the availability of components and raw materials? If so, how have they affected spare part lead times?
What are the benefits for integrating M3 and CPQ data?
How to define the scope of the items included in the spare part lead time update?
What values are updated in M3 and CPQ?
Is it possible to scale the use of automated update tool to other warehouses globally?
Data integration – three of the five IT managers & data architect
Why there has not been a data integration between M3 and CPQ?
How complex it would be to create the integration between M3 and CPQ to perform automated calculations?
How should data integration between M3 and CPQ be implemented?
Will this proposed calculation tool have any effect on the data warehouse's capability to execute other organizational automations/updates?
What additional software's are needed to properly execute the planned automated calculation tool?
Is it possible to use some tool in this work to push the data to target data warehouse more efficiently rather than using a traditional data warehouse insert which will take long time to complete? Since the data warehouses function in Microsoft SQL server ecosystem.

Appendix 4. How Lead Times are calculated for spare part items (Old logic)

Item Category	Description	Case	Lead time
Purchase Item	Purchased FFA	Factory purchasing team handles these	Lead time (set by purchasing team)
Distributed item	Part from factory warehouse	Safety stock	5 days
		No safety stock	lead time + 2 + 0 to 4 days*
Distributed item	Picked set from Vantaa factory	All set components have safety stock	5 days
		All components don't have safety stock	Longest lead time (component) + 2 + 0 to 4 days*
Distributed item	Machined part from Vantaa factory	Safety stock (main item)	5 days
		Safety stock (all components)	Lead time + 5 (buffer) + 9 (safety) + 2 + 0 to 4 days*
		No safety stocks	Lead time (main item) + Lead time (component) + 9 (safety) + 2 + 0 to 4 days*
Manufactured item	Sets DO-part from Vantaa factory	All set components/set have safety stock	2 days
		All components don't have safety stock	Longest lead time (component) + 2 + 0 to 4 days*
Manufactured item	Sets picked from Vantaa factory	All set components have safety stock	2 days
		All components don't have safety stock	Longest lead time (component) / PTF + 2 + 0 to 4 days*

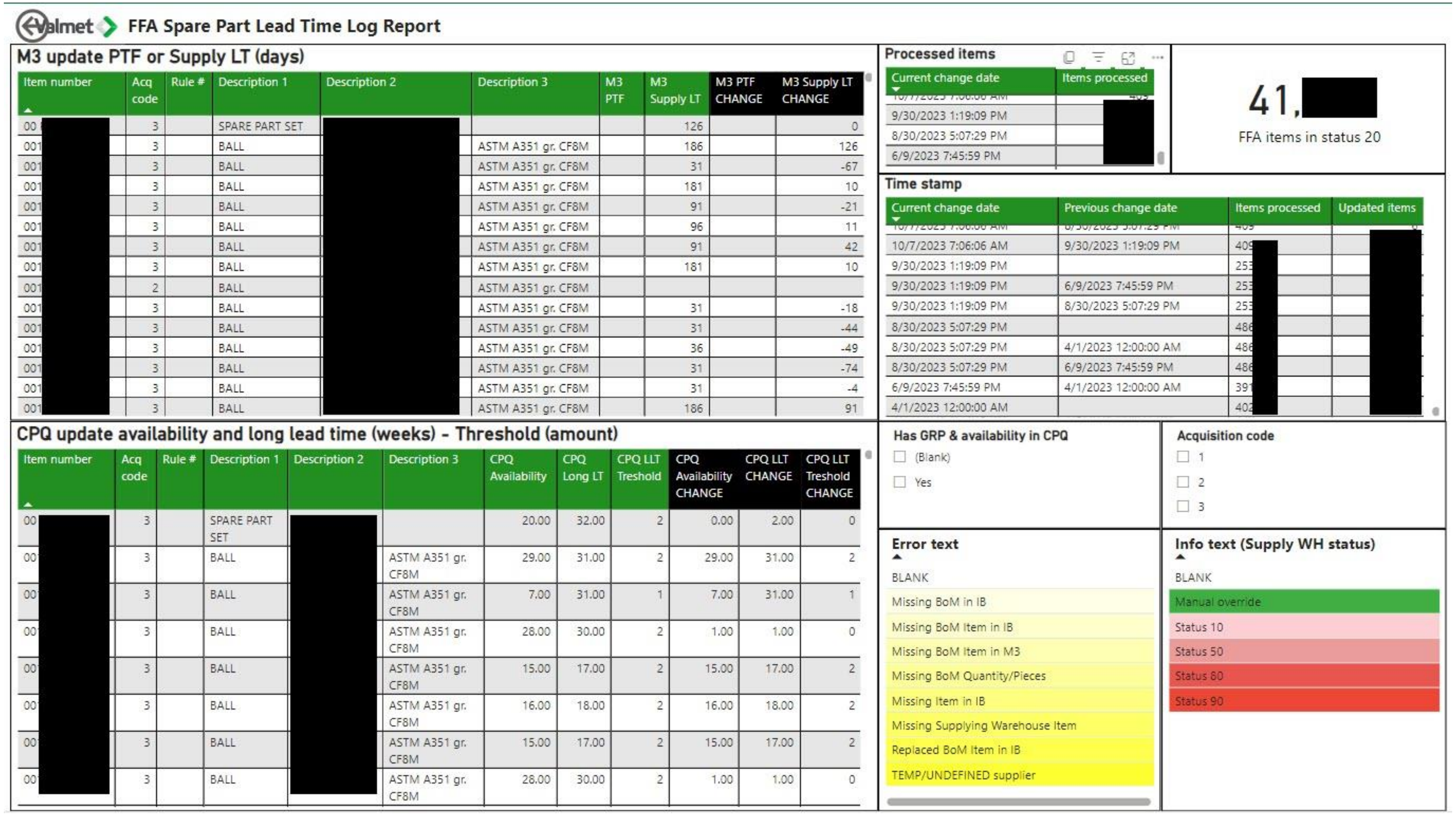
* Round up PTF to fives (for example 42 + 0 to 4 = 45 or 30 + 0 to 4 = 30).

Appendix 5. How Lead Times are calculated for spare part items (New logic)

Item category	Description	Example item	Case	Calculation logic
Purchase item	Purchased FFA	xxxx	Every PO item in FFA	Lead time****
Distribution item	Part from Vantaa factory	xxxx	Safety stock	2 days
			No safety stock	Factory lead time + 2 + 0 to 4 days*
		xxxx	Components with painting process** (safety stock)	5 days
			Components with painting process** (no safety stock)	Factory lead time + 2 days + 1 (painting buffer)** + 0 to 4 days*
Distribution item	Part from USA factory	xxxx	Safety stock	Picking time + transportation time + 0 to 4 days*
			No safety stock	Component lead time + picking time + transportation time + 0 to 4 days*
Distribution item	Part from China factory	xxxx	Safety stock	Picking time + transportation time + 0 to 4 days*
			No safety stock	Component lead time + picking time + transportation time + 0 to 4 days*
Distribution item	Part from Germany factory	xxxx	Safety stock	Picking time + transportation time + 0 to 4 days*
			No safety stock	Component lead time + picking time + transportation time + 0 to 4 days*
Distribution item	Part from Korea factory	xxxx	Safety stock	Picking time + transportation time + 0 to 4 days*
			No safety stock	Component lead time + picking time + transportation time + 0 to 4 days*
Distribution item	MO (Picked set) from Vantaa factory	xxxx	All set components have safety stock	2 days (product structure)
			All components don´t have safety stock	Factory lead time (component)/PTF + 2 + 0 to 4 days*
		xxxx	Components with painting process** (safety stock)	5 days
			Components with painting process** (no safety stock)	Factory lead time + 2 days + 1 (painting buffer)** + 0 to 4 days*
Distribution item	MO (Machined) from Vantaa factory	xxxx	Safety stock (main item)	2 days
			Safety stock(all components)	Factory Lead time + 5 (machining buffer) + 2 + 0 to 4 days*
			No safety stock	Factory lead time (main item) + factory lead time (component) + 2 + 0 to 4 days*
Manufactured item	Sets DO-part from Vantaa factory	xxxx	All set components have safety stock	2 days
			All components don´t have safety stock	Longest factory lead time (component) or PTF + 2 + 0 to 4 days*
Manufactured item	Sets picked from Vantaa factory	xxxx	All components have safety stock	5 days***
			All components don´t have safety stock	Longest factory lead time (component) or PTF + 2 + 0 to 4 days*

*Round up to fives (for example 42 + 0 to 4 = 45 or 30 + 0 to 4 = 30)
**Rule applies to single actuator parts - one additional day is added to the calculation
***Tool calculates PTF value so that items are first delivered as distribution item to spare part warehouse
****Purchasing team is responsible for updating the purchase item lead times

Appendix 6. Power BI log report for monitoring the update process



FFA Spare Part Lead Time Log Report

M3 update PTF or Supply LT (days)

Item number	Acq code	Rule #	Description 1	Description 2	Description 3	M3 PTF	M3 Supply LT	M3 PTF CHANGE	M3 Supply LT CHANGE
00[redacted]	3		SPARE PART SET	[redacted]			126		0
001[redacted]	3		BALL	[redacted]	ASTM A351 gr. CF8M		186		126
001[redacted]	3		BALL	[redacted]	ASTM A351 gr. CF8M		31		-67
001[redacted]	3		BALL	[redacted]	ASTM A351 gr. CF8M		181		10
001[redacted]	3		BALL	[redacted]	ASTM A351 gr. CF8M		91		-21
001[redacted]	3		BALL	[redacted]	ASTM A351 gr. CF8M		96		11
001[redacted]	3		BALL	[redacted]	ASTM A351 gr. CF8M		91		42
001[redacted]	3		BALL	[redacted]	ASTM A351 gr. CF8M		181		10
001[redacted]	2		BALL	[redacted]	ASTM A351 gr. CF8M				
001[redacted]	3		BALL	[redacted]	ASTM A351 gr. CF8M		31		-18
001[redacted]	3		BALL	[redacted]	ASTM A351 gr. CF8M		31		-44
001[redacted]	3		BALL	[redacted]	ASTM A351 gr. CF8M		36		-49
001[redacted]	3		BALL	[redacted]	ASTM A351 gr. CF8M		31		-74
001[redacted]	3		BALL	[redacted]	ASTM A351 gr. CF8M		31		-4
001[redacted]	3		BALL	[redacted]	ASTM A351 gr. CF8M		186		91

Processed items

Current change date	Items processed
9/30/2023 1:19:09 PM	[redacted]
8/30/2023 5:07:29 PM	[redacted]
6/9/2023 7:45:59 PM	[redacted]

41,[redacted]
FFA items in status 20

Time stamp

Current change date	Previous change date	Items processed	Updated items
10/7/2023 7:06:06 AM	9/30/2023 1:19:09 PM	409[redacted]	[redacted]
9/30/2023 1:19:09 PM		253[redacted]	[redacted]
9/30/2023 1:19:09 PM	6/9/2023 7:45:59 PM	253[redacted]	[redacted]
9/30/2023 1:19:09 PM	8/30/2023 5:07:29 PM	253[redacted]	[redacted]
8/30/2023 5:07:29 PM		486[redacted]	[redacted]
8/30/2023 5:07:29 PM	4/1/2023 12:00:00 AM	486[redacted]	[redacted]
8/30/2023 5:07:29 PM	6/9/2023 7:45:59 PM	486[redacted]	[redacted]
6/9/2023 7:45:59 PM	4/1/2023 12:00:00 AM	391[redacted]	[redacted]
4/1/2023 12:00:00 AM		402[redacted]	[redacted]

CPQ update availability and long lead time (weeks) - Threshold (amount)

Item number	Acq code	Rule #	Description 1	Description 2	Description 3	CPQ Availability	CPQ Long LT	CPQ LLT Treshold	CPQ Availability CHANGE	CPQ LLT CHANGE	CPQ LLT Treshold CHANGE
00[redacted]	3		SPARE PART SET	[redacted]		20.00	32.00	2	0.00	2.00	0
00[redacted]	3		BALL	[redacted]	ASTM A351 gr. CF8M	29.00	31.00	2	29.00	31.00	2
00[redacted]	3		BALL	[redacted]	ASTM A351 gr. CF8M	7.00	31.00	1	7.00	31.00	1
00[redacted]	3		BALL	[redacted]	ASTM A351 gr. CF8M	28.00	30.00	2	1.00	1.00	0
00[redacted]	3		BALL	[redacted]	ASTM A351 gr. CF8M	15.00	17.00	2	15.00	17.00	2
00[redacted]	3		BALL	[redacted]	ASTM A351 gr. CF8M	16.00	18.00	2	16.00	18.00	2
00[redacted]	3		BALL	[redacted]	ASTM A351 gr. CF8M	15.00	17.00	2	15.00	17.00	2
00[redacted]	3		BALL	[redacted]	ASTM A351 gr. CF8M	28.00	30.00	2	1.00	1.00	0

Has GRP & availability in CPQ
- (Blank)
- Yes

Acquisition code
- 1
- 2
- 3

Error text
- BLANK
- Missing BoM in IB
- Missing BoM Item in IB
- Missing BoM Item in M3
- Missing BoM Quantity/Pieces
- Missing Item in IB
- Missing Supplying Warehouse Item
- Replaced BoM Item in IB
- TEMP/UNDEFINED supplier

Info text (Supply WH status)
- BLANK
- Manual override
- Status 10
- Status 50
- Status 80
- Status 90

Appendix 7. Power BI report for monitoring lead time development