The role of procurement in enhancing the project scheduling process

Lappeenranta–Lahti University of Technology LUT

Master’s Programme in Supply Management, Master's thesis

2024

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Examiners: Professor Anni-Kaisa Kähkönen

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ABSTRACT

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LUT School of Business and Management

Business Administration

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Master’s thesis

2024

80 pages, 25 figures, 5 tables and 5 appendices

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Keywords: Project scheduling, procurement schedules, lead time information

This thesis examines the current scheduling process of a Finnish technology organization, and how within this process information on schedules, lead times, and their changes is communicated between the central departments. Through this research, it is studied how procurement could support other departments in this process. Investigation into the scheduling process was done through the analysis of delays that occurred in the processes of one previous project.

This thesis was conducted as a case study by using a mixed-method approach. The data utilized in the research included purchase order information, engineering release data, project schedules, meeting notes, and insights from employees. The quantitative analysis methods included describing the data with various graphs, tables, and a one-way ANOVA test. Qualitative methods included interviews with eight employees to discuss the current processes and ways of working.

According to the discussions relating to the current process, an updated process was created for effective communication of lead time information. Overall, it was concluded that procurement could support scheduling and other departments by providing accurate and timely information, especially on lead times, schedules, and their changes. It was found that for the inspected project, the most significant causes of delays were external factors, notably the Ukrainian war and resulted component availability challenges, which were intensified by the product model including many of these components, and the high workload within and outside of the organization.

TIIVISTELMÄ

Lappeenrannan–Lahden teknillinen yliopisto LUT

LUT-kauppakorkeakoulu

Kauppatieteet

Vilja Aalto

Hankinnan rooli projektin aikataulutusprosessin tukemisessa

Kauppatieteiden pro gradu-tutkielma

2024

80 sivua, 25 kuvaa, 5 taulukkoa ja 5 liitettä

Tarkastajat: Professori Anni-Kaisa Kähkönen ja Tutkijaopettaja Mika Immonen

Avainsanat: Projektien aikataulutus, hankinta-aikataulu, hankinta-aika tieto

Tämä tutkielma tutkii suomalaisen teknologiayrityksen aikataulutusprosessia, ja miten tässä prosessissa tietoa aikatauluista, hankinta-ajoista, ja niiden muutoksista kommunoidaan keskeisten sisäisten sidosryhmien välillä. Tämän tutkimuksen kautta selvitettiin miten hankinta voisi tukea muita toimintoja tässä prosessissa. Aikataulutusprosessin tutkiminen tehtiin analysoimalla myöhästymiä, jotka ilmenivät yhden aikaisemman projektin prosesseissa.

Tämä tutkielma suoritettiin tapaustutkimuksena käyttäen monimenetelmällistä tutkimustapaa. Tutkimuksen suorittamiseen käytetty data muodostui ostotilausten tiedoista, suuunnitteluvapautuksista, projektiaikatauluista, palaverimuisitoista, ja työntekijöiden näkemyksistä. Kvantitatiiviset tutkimusmeneltemät sisälsivät datan analysoimista kuvaajien, sekä yksisuuntaisen ANOVA testin avulla. Kvalitatiiviset tutkimusmenetelmät pitivät sisällään haastatteluja kahdeksan yrityksen työntekijän kanssa, joiden kanssa keskusteltiin nykyisistä prosesseista ja työtavoista.

Nykyiseen prosessiin liittyvien keskustelujen perusteella luotiin päivitetty prosessi hankinta-aikatietojen tehokkaaseen kommunikointiin. Tutkimuksessa todettiin, että hankinta voi tukea aikataulutusta ja myös muita toimintoja välittämällä täsmällistä ja oikea-aikaista tietoa erityisesti hankinta-ajoista, aikatauluista ja näiden muutoksista. Analysoidussa projektissa havaittiin, että merkittävimmät viivästyksien aiheuttajat olivat ulkoiset tekijät, erityisesti Ukrainan sota ja siitä aiheutuneet komponenttien saatavuushaasteet, joiden vaikutusta voimisti organisaation sisäinen, ja ulkoisten toimijoiden työkuorma sekä tuotemalli, joka sisälsi useita komponentteja, joissa oli saatavuushaasteita.

ACKNOWLEDGEMENTS

After almost five years, my time at LUT University is coming to an end, and I would like to express my gratitude to people that have been with me along this journey.

First, I would like to thank my supervisors at LUT for all their guidance during this thesis. I would also like to thank my supervisor in the case organization for valuable insights and support during this whole process. I also want to acknowledge all people within the company that were always ready to help and share their valuable knowledge.

I am grateful to my family and friends for their continuous support and cheering me on, not only during this thesis, but during all my academic years. This would not have happened without you! During my years at LUT, I got to have many amazing experiences and most importantly share them together with amazing people, so thank you, you made this all so much fun!

Vilja Aalto

20.5.2024

SYMBOLS AND ABBREVIATIONS

Abbreviations

ERP	Enterprise Resource Planning
GP	Global Planning. The scheduling department in the case organization.
LDP	Local Delivery Planning. The department responsible for overseeing production management in the case organization.
LLI	Long Lead Time Item. Items that have a lead time that is particularly long compared to others in the structure, commonly more than 10-15 weeks.
MRP	Material Requirements Planning
PN	Production Notification. Name for an engineering release in the case organization.

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1 Introduction

These days, procurement is recognized as a strategic function that can aid organizations in better adapting to constantly changing and unpredictable environments (Rane & Narvel 2021). However, in the context of project business, procurement functions' ability to answer to the challenges posed by volatile environments, is heavily dependent on the operations and collaboration between other key functions such as project scheduling and engineering. (Laari, Lorenz, Jonsson and Lindau 2023). As the efficiency and ability of an organization to answer to risks and demands posed by the environment are directly linked to their processes, firms need to be equipped to continuously develop their functionality (Wagner and Eggert 2016; Bode, Wagner, Petersen, and Ellram 2011).

In the global, competitive, and rapidly changing environment of today, projects have become intricate and complex entities, that are composed of complicated processes that span not only the whole organization but also subcontractors and suppliers. This increases the level of uncertainty in a project and distributes it to a broad set of processes. (Thamhain 2013; Thamhain 2004; Thamhain & Wilemon 1999) For this reason, it is important to examine individual processes of an organization in detail, to find ways in which they could be better supported.

1.1 Research background

It has been long recognized that uncertainty is one of the main characteristics of projects (De Meyer, Loch & Pich 2002). In the environment of today, this uncertainty appears to be particularly relevant as organizations experience risks and uncertainty from their external environments. Within the past years global unrest, the COVID-19 pandemic, the Ukrainian war, and accelerating climate change have drastically affected the global business environment. As modern businesses have increasingly global and complicated supply chains, they experience the effects in their operations. (Sodhi & Tang 2021; Ziółkowski 2023) When it comes to project procurement, this less predictable environment can cause instability in all processes involved (Rane & Narvel 2021). The challenges for procurement operations can showcase themselves as challenged component availability, shocks in supply and demand, increased delivery times, and overall uncertainty on item lead times (Ziółkowski 2023).

In earlier studies, the most effective tools and modelling approaches for project scheduling have been considered at large, like Felberbauer, Gutjahr, and Doerner (2019) and Pinto (2013) but the literature on procurement scheduling under uncertainty remains scarce. Despite there being previous research that recognizes the risks of unsuccessful scheduling, such as Dixit, Srivastava, and Chaudhuri (2014), especially a viewpoint on how procurement could support this process, is not broadly researched. There however have been various studies conducted, that recognize the key role of procurement as well as studies on integrating procurement more closely to other operations such as Laari Lorentz, Jonsson and Lindau (2023) and Tassabehji and Moorhouse (2008). A variety of scientific research has focused on the importance of communication and information sharing within an organization, to reach successful business processes, but there are not so many that consider the specific communication or information exchange processes between the procurement and scheduling departments. For example, according to Mentis (2015) recognized causes for projects slipping from the original schedule are weak communication, and limited transparency, and likewise Sharma, Maheshkar, and Poulose (2023) present that organizations do not utilize the information available to them to its full potential. This creates a motive to investigate these concepts in more detail in an organizational context.

1.2 Thesis questions

The objective of this study is to clarify the current scheduling process and one of its sub-processes and examine if the current method of maintaining data on long delivery times of items is practical or should be improved. To reach this objective, this research investigates what is the actual process of how the information on long item delivery times is currently utilized in the schedule planning process, and if there are any ways in which procurement could improve this process. The aim is to investigate the inputs provided by procurement departments from the viewpoint of other internal departments using that information, and if they find that the data could be managed and communicated in different ways. By clarifying to the procurement departments how this data is utilized in practice, this process could be further developed, which could help minimize risks associated with procurement scheduling, increase visibility of the process, and improve the flow of information.

In order to reach the previously mentioned objectives, the research questions are set accordingly. As in the literature the risks of inefficient scheduling, such as schedule and budget overruns, inventory, and dissatisfied customers have been widely recognized, for instance by Lorko, Servátka, and Zhang (2023) and Dixit et al. (2014), it can be seen as important to examine how inefficient scheduling could be managed. This topic has been studied earlier by Sami Ur Rehman, Thaheem, Nasir, and Khan (2022), but in the context of ICT solutions, which is why integrating a viewpoint of procurement was chosen for this thesis. In order to investigate this topic from the viewpoint of procurement, the main research question was set as:

> *"How could the risks in the project scheduling process be minimized with support from procurement?"*

In order to investigate this further in the context of the case organization, the first sub-question was defined as:

> *1. "How is the current project scheduling process operated in the case company?"*

It has been presented in the literature, that through support from procurement, operations such as sales and operations planning, and marketing can be improved (e.g. Laari et al. 2023; Wagner and Eggert 2016). Considering also that procurement has been noted as a strategically important function, for example by Tassabehji and Moorhouse (2008), in this thesis it was seen as noteworthy to investigate if also in the context of project scheduling, enhancements could be gained through procurement. This is why the second sub-question was set as:

> *2. "How can project scheduling be enhanced in the case company through the means of procurement?"*

1.3 Research Method

In this thesis, a case study is performed in a large Finnish technology company, with the aim of examining how the internal process of project scheduling and if through support from procurement, project schedules could be planned more efficiently. A central part of this research is to investigate how the information maintained by the procurement departments on long delivery times is utilized by other internal departments when planning and updating schedules, and if this current way of maintaining information is efficient when communicating between different internal operations. By investigating the current process, the target is to find ways in which inputs from procurement could more efficiently support other operations in the current scheduling process. In order to understand the scheduling process, an analysis was performed on a previous project and its process, to understand the instances where the schedule experienced delays.

1.4 Key concepts

Procurement: Procurement in a business context, refers to the process of obtaining the needed resources for the organization, at the right time, with the right price and amount. These resources can be goods or services, and to obtain them, organizations utilize different strategies and processes. (Sollish and Semanik 2012, 1)

Resource dependency theory: Resource dependency theory (RTD) considers the organization’s need for resources and the effect it has on organizational behaviour when the acquisition of these resources is dependent on other actors. As this dependence on actors outside of the organization may create disadvantages, organizations create strategies and internal processes to adapt to their circumstances. (Archibald 2017)

Uncertainty: Uncertainty, in the context of this thesis, refers to events that are in nature unforecastable, unpredictable, and difficult to measure (Jurado, Ludvigson, and Ng 2015). Uncertainty is commonly tied to the lack of information (Kuchta, Canonico, Capone, and Capaldo 2023).

1.5 Theoretical framework

In the below figure, the framework presents the theoretical background of this thesis. This framework is used to clarify from the theoretical viewpoint, the phenomenon presented in the research. The framework is based on the theory of resource dependence, and it shows the process of external resource dependence and uncertainty influencing the internal processes of an organization. The figure depicts, that the effectiveness of internal processes directly influences how uncertainty and interdependence are managed in the external environment. This in turn affects how much dependency and uncertainty influence the operations of an organization.

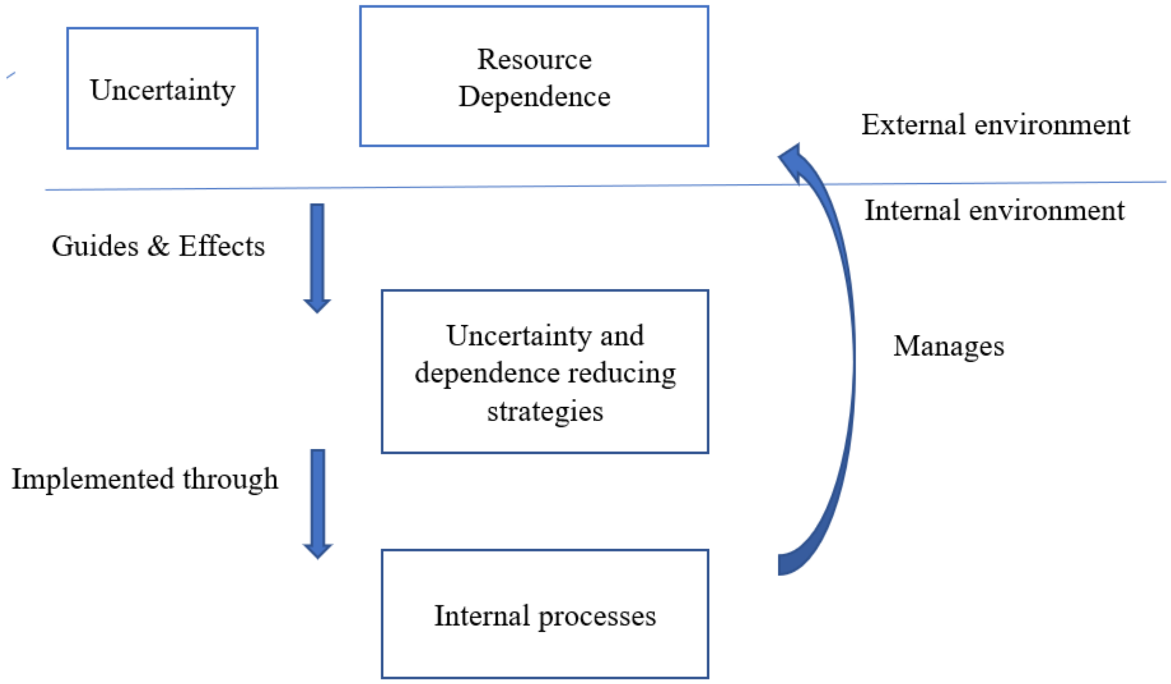

Figure 1 Framework on RDT influence on internal process.

Figure 1 shows, how resource dependency creates uncertainty derived from the external environment, which affects the behavior of a firm and the strategies utilized to cope with and manage uncertainty and dependencies. These strategies are implemented through internal processes, and their effectiveness is dependent on how effective and working the internal processes are.

1.6 Structure of the thesis

This thesis is structured as follows. First, the theoretical background of the thesis is presented through resource dependence theory, along with the concepts of planning operations, information processing, and general business processes. In this section, the concept of uncertainty is also considered in more detail. After this, it is presented how in previous academic literature the topics of procurement and its role are discussed, along with project procurement and scheduling processes. In the research design section, the methodological approach of the thesis is introduced with descriptions of the quantitative and qualitative research data. In the following empirical study segment, the results of the interviews and project analysis are presented. Following the results, the discussions and conclusions segment will present an analysis based on the results of the interviews, and the conducted data analysis, and compare these to the theoretical background. Along with implications for future research this thesis is finished with the limitations.

2 Theoretical background

In this section, the theoretical background of the thesis will be presented. First, the chapter will start with presenting resource dependency theory (RDT), and how it relates to concepts of information processing and business processes. After this, the section will move on to introduce procurement, how it functions in project business, and how this has been considered in previous academic literature, along with topics of project scheduling.

2.1 Resource dependency theory

Organizations create value from resources, but evidently in most cases are not able to acquire and access these resources by themselves. Having to rely on external actors creates uncertainty as the organizations themselves cannot be sure of the actions of others. This is the basis of resource dependence theory (RDT), which presents that businesses are dependent on other organizations for their critical resources, which affects the way they behave (Hillman, Withers, and Collins 2009). These dependencies between actors are commonly mutual and referred to as "interdependencies" and seen as the force driving firms into inter-organizational relationships. (Drees and Heugens 2013, 1666)

Firms strive to gain better control over their environment, alleviate dependencies, and control the uncertainty resulting from having to rely on external parties, by developing strategies and processes. When the aim is to decrease dependency on other organizations, these actions are often focused on power relations, and increasing the firm's autonomy and own power over external actors. Successful strategies are described as those that can adapt to the environment and available resources. (Davis and Cobb 2010, 23; Hillman et al. 2009)

Typically, in RDT literature the strategies firms use to cope with their external dependencies are divided into buffering or bridging strategies, even though usually a mix of the two is used. Buffering strategies focus on reducing dependence and minimizing risks by putting on place safeguards that act as buffers in case of a disturbance, which can be caused for instance by material suppliers and resource shortages. These buffers can be in the form of safety stock, systems that predict changes in the environment, and other mechanisms that protect internal processes from external disruptions. Bridging strategies on the other hand focus on forming closer connections with suppliers, which can include actions such as information sharing or on a larger scale, alliances and even merging. (Bode, Wagner, Petersen, and Ellram 2011; Roundy and Bayer 2019)

When it comes to literature on uncertainty-reducing strategies, the general view in RDT research has been more on the macro-level, focusing on interdependencies prevalent in the external organizational environment, but it has been presented that a more micro perspective could be integrated into this view. A micro perspective on RDT considers also the internal interdependencies within the organization, for example how employees rely on each other when it comes to the introduction of dependency-reducing strategies. (Hillman et al. 2009; Jiang, Luo, Xia, Hitt, and Shen 2023) In a micro view, attention is paid to the internal power dynamics, for example between employees and subsidiaries, internal resource flows, and the interdependencies these resources create. As mentioned by Ozturk (2021) since the general focus of RDT is interested in the relationships regarding the external resources, it is important to also focus on the internal strategies and processes through which these are managed. In this thesis, RDT is used as the general framework explaining the internal processes and their motivation. Other theoretical concepts such as information processing and business processes will be deduced from and integrated with RDT. First, we consider the RDT in regard to procurement and planning functions and the relationship between the two, after which there will be a closer focus on the concept of uncertainty that is embedded in the RDT.

2.1.1 Resource dependence on procurement and project planning

Procurement has an integral role in the process of acquiring external resources for organizations and so is heavily guided by resource dependencies. Controlling risks caused by uncertainty and dependence such as late deliveries, unavailable resources, high prices, and inadequate quality are common processes for procurement operations. Due to the relevant position procurement has, when it comes to managing supplier relationships, the role in interdependency-reducing strategies and their implementation could be seen as considerable. (van Weele 2014) As an integrated function within the organizational processes, procurement is also internally dependent on the actions of other departments that it is closely connected to, such as engineering and project planning. As an example, procurement relies on engineering for item data and overall, on what needs to be purchased, and on the planning department for the procurement schedules and other guidelines.

RDT perspective can aid in understanding the project environments, and through recognizing external influences and relating risks guide what actions to take. Decision makers such as project managers can utilize this perspective to find weaknesses and strengths when deciding processes and strategies. (Cullen and Parker 2015; Hillman et al. 2009) The role of project planning in RDT could be considered similar to how RDT literature recognizes board and management contribution as giving access to resources. As maintaining schedules and allocating resources are a part of planning and project management operations, having a perspective that is aware of the required external resources and associated uncertainty could be seen as beneficial. (Cullen and Parker 2015; Jian et al. 2023) Planning operations can be seen as having a similar connection to procurement by making sure that the firm has access to needed resources and managing the overall view on how to execute processes. (Jian et al. 2023). Planning is also mutually dependent on other departments and the information they provide to operate efficiently.

It however could be noted that there is a difference when considering internal dependencies in procurement and planning, to external dependencies between an organization and its resources. In the external environment the goal is to reduce and control interdependencies, while in the internal environment, the goal is rather to achieve efficient and functional relationships which could even mean increased dependency and closeness, but not achieve control over other parties. In internal contexts, dependencies could be seen rather as barriers that can hinder the realization of internal processes and resource exchanges through which the external resource dependencies are managed. (Jian et al. 2023)

2.1.2 Resource dependency and information processing

As mentioned earlier according to Hillman et al. (2009) integrating RDT with other theories could be explored to bring new perspectives. As referred to in the previous chapter, functional internal processes are a prerequisite for the successful management of external dependencies and uncertainty. One critical resource for managing internal relationships is information. With its focus on information and efficiently functioning internal processes, the information processing view could be integrated to complete RDT. (Bode et al. 2011) This is also a relevant perspective since how successful the actions to reduce uncertainty are, are mentioned to be dependent on how functional the relationships and informational exchange are.

Organizations utilize many types of data as a basis for their decision-making (Srinivasan and Swink 2018). Modern supply chains produce detailed data on the activities occurring along many key operations such as logistics and production planning with solutions such as enterprise resource planning (ERP) (Maheshwari, Gautam, and Jaggi 2021). Procurement has commonly at their hand, internal data created from their operations but also external data that they have access to through external suppliers (Handfield, Jeong, and Choi 2019). To be able to utilize all this data effectively can be challenging, but if successful a major competitive advantage (Assunção, Calheiros, Bianchi, Netto, and Buyya 2015).

According to Bode et al. (2011) the greater the environmental uncertainty the business is experiencing, the more information it should have to be able to process and collect in order to sustain itself. Similar ideas are presented by Felin and Powell (2016) who state that organizations operating in volatile business environments need to have in place systems, that facilitate information sharing. They also point out that the information and capabilities needed in uncertain and high-risk environments do not come from singular employees but from systems and people that bring the information together. This is why information needs to be brought together in processes.

Firms can be investigated through an information processing perspective, which is focused on how information is processed in internal functions (Bode et al. 2011). By improving their information processing capacity, organizations that operate in volatile environments with a high level of interdependency can reduce uncertainty in their decision-making processes. (Srinivasan and Swink 2018; Zhu, Song, Hazen, and Lee. 2018)

By maintaining external relationships with their suppliers, firms can gain access to valuable data, and with internal vertical information systems, this information can be processed and used effectively when planning and updating strategies and plans. This information can come from suppliers in the form of component availability, material shortages, or shipment statuses. Even though typically this information is communicated to procurement, forwarding this information to other internal operations such as sales and operations planning is crucial in designating accurate responses. (Srinivasan and Swink 2018)

An important prerequisite for information processing capabilities is information and data visibility. Visibility refers to the availability and access to information that is accurate, current, and in appropriate format. Through good visibility, firms can formulate processes that use this data as an aid in decision-making, and with insights that are created from data, there can be found ways for operational improvements. This visibility in supply chains can be increased through lateral relationships with suppliers. (Srinivasan and Swink 2018) In Figure 2. there is presented an example of an internal process whose effectiveness is guided by the efficiency of information processing.

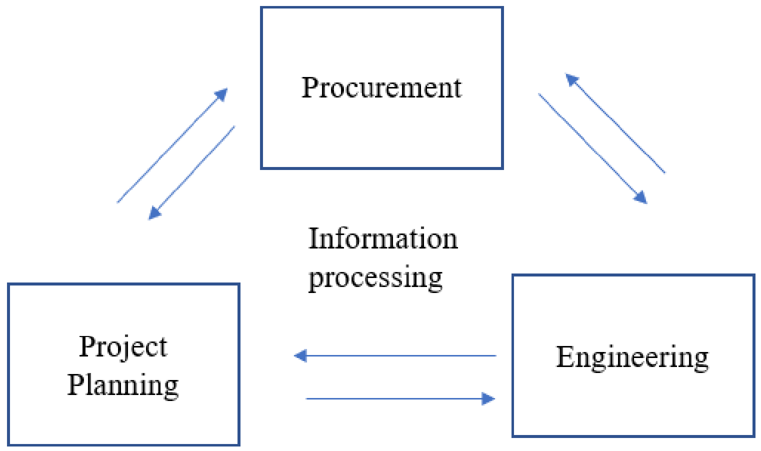

Figure 2 An example of an internal process.

2.1.3 Business processes and resource dependency theory

As previously mentioned, external dependencies and uncertainty control are managed through internal processes. Developed processes are a way in which companies strive to optimize their performance under resource dependency, which is why a detailed view of the current business processes is useful when utilizing the RDT perspective.

Processes are an essential part of business activities and with developed processes, organizations can lower the costs and time of their operations and reach competitive advantages (Hong Pham and Hadikusumo 2014; Dumas, La Rosa, Mendling and Reijers 2018, 1-2). A process can be defined as a chain of activities, events, and decisions through which value is created for the organization and customers. How well the processes are formed affects the efficiency and quality of business operations. (Dumas et al. 2018, 1-2) In large companies, the standardization of processes can create challenges due to complex and hidden processes and complicated communication networks (Hong Pham and Hadikusumo 2014). Duman et al. (2018, 15) present that to improve business processes organizations need to optimize their information usage and exchange.

2.1.4 Uncertainty in projects

As already mentioned in previous chapters, uncertainty is practically unavoidable when it comes to projects (De Meyer et al 2002). Although there are various different definitions for uncertainty depending on the context, Mentis (2015, 1) refers to uncertainty as “poorly or not quantifiable bad possible events”. A general understanding of uncertainty is that derives from a lack of knowledge and as a common feature of industrial projects, results in overruns in project costs and schedules (Kuchta, Canonico, Capone & Capaldo 2023; Szwarcfiter, Herer & Shtub 2023).

Mentis (2015) also notes uncertainty as being the main cause of issues with projects being on schedule and in his paper states that rather than the abstractness of uncertain events causing project slippage, the main issue is that they are not accounted for sufficiently in the project planning and execution phase. This is also stated as the cause for project schedule and budget slipping. Uncertainty in project schedules is formed by uncertainty in the main quantitative parameters of time, amount, and cost. Structural uncertainty derives from the schedule structure, the number of activities and their sequences, probabilities, and the number and probability of different critical paths. (Nazimko & Zakharova 2023)

In other academic literature, De Meyer et al. (2002) provide a more thorough categorization for different types of uncertainty. These four types of uncertainty are variation, foreseen and unforeseen uncertainty, and chaos. In most projects, several different types of uncertainty are experienced as a combination. Variation refers to activity values, that present in a range rather than in an exact value. For example, the assembly of a product might take between 1-3 weeks. This is caused by different small influences such as delays in component delivery and sick employees. Variation in one activity duration influences also the other following activities and their execution schedule. Overall, the level of uncertainty is dependent on the severity of the variation and its potential effect. The causes and effects of variation are however known beforehand. (Thamhain 2013)

Foreseen uncertainties are influences that are beforehand recognized but there is no certainty whether they will occur or not. Where variation was a sum of small singular influences, foreseen uncertainties are individual events. For these types of uncertainties, there are generally processes and plans in place, since the uncertainty and the possible effects are known, even if the probability is not certain.

Unforeseen uncertainties on the other hand are the events that are not and cannot be identified in the project planning stages, which means there are no planned responses defined. Unforeseen uncertainties can be caused by one event or derive from an unexpected combination of many known events. Chaos as a type of uncertainty is apparent in projects where there is significant uncertainty in every stage of a project to such a degree that outcomes cannot be defined in the planning stage. De Meyer et al. (2002) emphasize that projects characterized by great uncertainty should have preestablished ways of managing changes since they often experience situations where the project plan structure or tasks have to be redefined in the middle of carrying out the project.

Whereas traditional risk management approaches focus on specific events, risk management techniques, and roles, uncertainty management should be targeted towards learning and flexibility, and managing of variability apparent in the firm’s operations (Petit & Hobbs 2010; De Meyer et al. 2002; Platje & Seidel 1993). An important aspect of uncertainty management is to recognize and understand the sources of uncertainty. Effective communication within the organization’s teams, and support units that span the whole organization is recognized as an important factor when it comes to the reduction of uncertainty. (Thamhain 2013). Environmental uncertainty refers to the circumstances in an organization’s environment (Petit & Hobbs 2010).

2.2 Procurement and its role in business

The role of procurement as a business function has been documented and researched broadly in academic literature due to being at the center of continuous development over the years. This change towards viewing procurement as a strategic operation instead of purely transactional has been led by factors such as the introduction of new technologies, multi-tiered supply chains, and a business environment that is increasingly global and volatile. (Tassabehji & Moorhouse 2008)

The development of procurement has been occurring gradually since the 1980s, and along with increased global sourcing, and fragmented and complex supply chains, this evolution has been led by solutions such as materials requirements planning (MRP) and enterprise resource planning (ERP), through which businesses have started to move towards the integration of information and material flows (Mena, van Hoek & Christopher 2018, 8-13; Baily 2008, 36-37). Together with events that have increased vulnerability and risk such as natural disasters, political instability, and terrorism have called for more integrated, central, and strategic procurement that also operates in collaboration with other units (Mena et al. 2018, 8-13). For instance, when it comes to project business, due to its position, procurement constantly interacts with other operations such as engineering and manufacturing, and it has been concluded that cooperation and collaboration are needed between procurement teams and other business units to complete projects (Mena et al. 2018, 21; Rane, Narvel, & Bhandarkar 2020).

Today, it is recognized that procurement can be a value-adding activity that increases efficiency. When considering the significant impact of purchasing costs on the bottom line in the manufacturing industry, and that increasingly more materials and services are purchased rather than produced in-house, it is evident why procurement functions have received a more strategic and integral role. (van Weele 2014, 3; Baily 2008, 36-37; Mena et al. 2018, 1-2) There however might be differences internally within a company regarding the role of procurement and even though the procurement managers would recognize this strategic role, this view might not be acknowledged by all within the organization. (Tassabehji and Moorhouse 2008)

2.3 Role of procurement as a strategic and supporting operation

As the prominent role of procurement has been recognized in the literature, research has also increasingly been done to investigate how procurement activities could be better integrated and developed with other business operations and processes. For instance, some studies call for as presented by Laari, Lorentz, Jonsson, and Lindau (2023, 70), a more “business-wide perspective on procurement decisions." In their research, they studied the role of procurement in sales and operations planning through the integration of procurement into the demand and supply operations balancing process. They stated that the effectiveness of planning operations is dependent on how involved procurement is, due to the procurement operations knowledge on availability of resources. It was presented that by internal co-management, demand, and production plans could be aligned with those of procurement if there is enough information visibility and data transparency between procurement and other supply chain processes.

There is also earlier research conducted from the co-management perspective on the relationships and integration of procurement with different business units. Wagner and Eggert (2016) studied the internal and external co-management of purchasing and marketing operations, from the perspective of resource dependency theory (RDT). In their paper, co-management between procurement and marketing could appear for instance through information and know-how sharing and task coordination. If this co-management occurred between different units within the business, it was referred to as "intra-organizational" (Wagner & Eggert 2016, 28).

In a similar manner to Laari et al (2023), Wagner and Eggert (2016) also stated that for this cross-department operation to be successful, both processes need to have aligned goals, that could be achieved through enhancing relationships and commitment, through knowledge sharing. An aid in this open communication within cross-department would be roles that span boundaries and functions and increasing the knowledge of other departments' responsibilities and tasks, which will help in recognizing the strategic importance of each process and department. They, however, note that since cross-functionality and inter-organizational alignment possibly create increased constraints and lessen the freedom of employees, it should emerge from the overall strategy of the business and top management.

There have also been calls for the possibilities of procurement to take the role of an advisor and improve business agility. It has been proposed that there is still some lack of utilizing the full capabilities of procurement. Procurement can analyse internal and external data of a business, acquired from for instance suppliers, and if these analytics skills are used to their full potential, procurement could become an advisor through which strategic advantages can be gained. (Hackett Group 2015)

2.4 Procurement in project business

As noted previously, procurement has an important role in ensuring the business has the needed resources and in providing essential information from external stakeholders to internal ones. Procurement functions, and how they need to be managed differ depending on the nature of the business. When it comes to project business, in particular, procurement functions must be organized differently compared to businesses that produce consistently products with very little variety. Along with uncertainty and irregularity in demand, procurement functions also have to consider the high level of variety in financial and technical requirements that are associated with project business. These unique characteristics lead to complex dependencies and relationships with various supplies. (Dixit 2022) As projects can differ in their contents, choosing the right suppliers and evaluating their performance along the project is important (de Araújo, Alencar & de Miranda Mota 2017). Procurement that is driven by projects often needs integrated suppliers to combat the high-risk levels, but creating longevity in supplier relationships can be challenging, and due to unique requirements and complicated products that are high in value, suppliers often can have power over businesses. (Dixit 2022)

2.5 Project planning

In current literature and research, the planning process has been noted as one of the most crucial aspects of executing a project successfully (Artto & Wickström 2005). The tough competition in today's business environment has put pressure on businesses to get their products to market as fast as possible, and as an effect of this, the planning operations must be faster, which can lead to a situation where there are constant changes and updates to the procurement requests. (Rane, Narvel & Bhandarkar 2019) Rane and Narvel (2021) in their paper present that the current project procurement management is not flexible enough to account for these quick changes, and that there is a need for processes that are agile in nature to be able to respond to the changing environment. It has also been recognized that the failure of a project can usually be traced back to those planning stages (Pinto 2013). The main constraints that limit projects are resources and time, and as projects are commonly defined by their complexity and uncertainty, they require precise strategies to share and target the finite resources effectively (Bailey 2008, 276- 277).

Projects are linked to their environments, which is why one of the first steps in project planning is defining the project environment, objectives, and how they will be achieved. (Artto and Wickström 2005; Bailey 2008, 276- 277). In this stage, procurement is usually capable of providing vital information when it comes to understanding the project environment, and risk management. (Bailey 2008, 276- 277)

Companies operating in the project business also have high incentives to complete projects according to the planned schedule, to avoid financial incentives such as penalty fines, which can lead to overruns of their budget (Pinto 2013; Grushka-Cockayne, Erat, & Wooten 2018, 377-378). If the planning process is not thorough enough, inaccurate procurement scheduling can lead to unavailable items in the manufacturing sites, production delays, and high inventory for non-essential items (Dixit et al. 2014).

Failure to control project lead time is also presented commonly as the main reason for project implementation failures and financial losses. Once the control is lost, it can be difficult to regain, which is why to execute a project successfully, the project schedule should be accurate. (Barkalov Kurochka & Kalinia 2021) Respectively, with accurate procurement scheduling project schedules and cost overruns can be avoided (Shakhsi-Niaeia and Sajadian 2021).

There can be various reasons why a project schedule experiences delays, but some recognized causes for projects slipping from the original schedule have to do with information sharing such as weak communication, and limited transparency (Mentis 2015). An important factor in the process of ensuring that the purchased items are delivered on time is the knowledge of the typical supplier lead time and when the item is required by the company. If there is no information available for central departments on lead times, or the information is not correct, the required item dates might not be achievable by procurement and suppliers. (Baily 2008, 188) Process automation is presented as one solution to this by being able to predict project completion time (Rane & Narvel 2021).

When considering the risks relating to project procurement being on schedule, particular hinderance can be caused by so-called “major equipment”, which is equipment that is essential from the viewpoint of the whole project, and usually includes complex technology and special requirements (Yeo & Ning 2006, 124). Procurement of major equipment differs from that of regular bulk materials in that there is no inventory, the lead times are significantly longer, and delivery time uncertainty is high. Due to these specialties, major equipment can be a source of significant uncertainty to the whole project's performance. This uncertainty is commonly managed by time buffers that have been defined according to the perception of the seriousness of the risk. Time buffers protect other phases of the process from disruptions caused by late delivery. (Yeo & Ning 2006)

2.6 Scheduling process and models

The process of determining a procurement schedule begins from the planning process of the overall project schedule, where in the early stages it is defined how the different project phases are executed, the needed activities are defined, and their sequence and durations are assigned (Sami Ur Rehman et al. 2022; Mohammadian 2019, 2-7). The sequence of actions is determined by the different relationships and dependencies, one of the common dependencies being the so-called “Finish-to-start”, which means a certain task must be finished before the next one can begin. Durations for each activity can be estimated using historical data and knowledge of the employees completing the activities. (Mohammadian 2019, 2-7)

One common way to plan project schedules is the end-date-driven way, in which the project finish date is first established, from where the scheduling for each activity is done by working backward. Large-scale projects, which are common in for instance industrial manufacturing companies, are usually high in complexity and include a vast number of operations with their interdependencies. In these instances, the best way is to divide the project into smaller segments and processes which are easier to tackle one by one compared to the whole project entity. (Pinto 2013)

There also exist several studies that have focused on creating different tools and models for project and procurement schedule creation that would be able to account for common issues prevalent in the project procurement scheduling phase. For example, stochastic modelling has been presented as a tool by Felberbauer et al. (2019) when scheduling project action durations and assigning resources in an uncertain environment. Similar research has been conducted by Barkalov et al. (2021) where stochastic modelling has been presented as a solution that could help in project time management when it comes to defining optimal labour resources.

It has however been argued that stochastic modelling is not always a practical application when it comes to procurement scheduling in projects, due to projects often being unique in nature, which means there is rarely enough historical data available for accurate stochastic modelling. For this reason, Dixit et al. (2014) in their paper developed a procurement scheduling model with fuzzy numbers. They mention that assigning a schedule for procurement activities in a complex manufacturing project context is challenging, due to difficulties in forecasting durations for any activity in the process. This is caused by the numerous steps in complicated manufacturing processes that are complexly interdependent. Another layer of difficulty is added by item and material lead times that usually cannot be forecasted accurately in the planning phase, creating uncertain availability dates. Due to these reasons, Dixit et al. (2014) propose that procurement scheduling should be synchronized with production planning since traditional procurement scheduling has not considered the internal interdependencies between the work schedules and other departments.

3 Research design

This section will introduce the methodological approach used in the research, and the types of data used to conduct the research. First, this section will describe the case this thesis is based around, after which the following chapter will present the research methods and design in more detail. After this, the types of quantitative and qualitative research data along with the methods that were used in further analysis are introduced.

3.1 Case description

This research is conducted as a case study for a large Finnish technology company that operates in the sector of industrial equipment. The case study approach is commonly used to investigate business failures and successes (Eriksson & Kovalainen 2008). For determining, and finding links between cause and effect, case research has been presented as a particularly effective research method compared to others. It is also recognized that insights gained from case research can be very valuable and impactful to practice, especially when it comes to investigating operations management in business. (Voss, Tsikriktsis & Frohlich 2002)

As the identity of the company investigated in this thesis cannot be publicized, identifying details are not disclosed. The company has its headquarters in Finland but operates on a global scale on many continents. This thesis focuses on the operations of one of the business lines in the organization, which is one of the five existing business lines. This specific business line operates in project business and delivers projects of different scales. The projects can consist of delivery of large production units, smaller equipment, or for instance machine rebuilds depending on the scope of what was sold. Within this business line, this thesis is conducted for the procurement function, which affects the viewpoint the results are considered.

Scheduling is a complex function in the case organization, due to attempts to balance production capacity and assembly schedules, multiple projects ongoing at the same time, and the various departments involved with their own schedules. Making sure all the schedules are aligned and coherent with each other is essential, while also having control over possible disruptions. In the case organization, there had been noted projects slipping from their original schedules, which created a motive to investigate the scheduling process and find factors that can cause schedule delays in the different phases of the project delivery process, and as a whole, how information on lead times is communicated and utilized between the central departments in this scheduling process. As this study is conducted for the procurement function, the focus was on how procurement could better support scheduling, and pointed towards a section of the scheduling process that considers the creation of the "engineering schedule", since it is the most notable schedule defining the procurement schedule. Engineering schedules determine the timetable for engineering departments when their functions should start and finish, and when the procurement functions are expected to begin and end. These "action points" also define the time left for other operations such as the following warehousing and logistics functions. Departments involved in this process are scheduling (GP), engineering, production management (LDP), and procurement, which is why they were the departments included in this study.

In order to investigate the scheduling process and possible delays, it was seen as best to limit the scope and choose one completed project. This way by comparing the planned and actual schedules it would be possible to note if there have been delays and investigate their causes. One project was chosen as a case example, based on the attributes of relevance, fitting project scope, number of delays, common project structure, and the opinion of people working in managerial positions in the procurement, LDP, and GP departments. A more detailed explanation of the conducted analysis and attributes of the project is visible in the latter sections, with the following section presenting the methodology and research process.

3.2 Methodology

As mentioned earlier, this research was conducted as a case study and was carried out with a mixed-method approach. Mixed-method approach refers to the usage of both quantitative and qualitative approaches in data collection (Saunders, Lewis, and Thornhill 2016). One main advantage of a mixed-method approach is that by combining different research methods, the limitations of using only a singular method can be mitigated, and the advantages of both methods combined (Turner, Cardinal & Burton 2017; Creswell 2009, 203). Topics that are high in complexity can also be difficult to address by utilizing only a singular method (Creswell 2009, 203).

Quantitative research methods were chosen for this study for the ability to analyse large amounts of data. Since purchase order data and data considering the start and finish dates of different operations are in numerical form, in order to analyse possible delays and form timelines, quantitative analysis methods were needed. These quantitative methods included data analysis through graphs and tables, and a one-way ANOVA test.

In order to access information that was not attainable through quantitative data, for instance, detailed accounts of past events, qualitative methods were also required. This led to the thesis being conducted with a mixed-method approach. According to Saunders et al. (2016), data collection methods used when analysing non-numerical data are widely defined as qualitative. This qualitative approach was seen as suitable for the context of this research, since as mentioned by Eriksson and Kovalainen (2008), it is used to investigate specific phenomena in their own context. A relevant application for this master's thesis was the possibility to use qualitative research in elaborate analysis of important business processes and how they are executed in the everyday context (Eriksson & Kovalainen 2008). A qualitative approach is also presented as beneficial when investigating a topic that has not been researched before in close detail (Ghauri & Grønhaug 2002). Qualitative methods included interviews, and the gained data was analysed by using qualitative content analysis. In qualitative content analysis, the material is categorized or grouped based on its content to relevant themes or categories. What information is included and what left out is dependent on its relevance to said category. These categories or themes can be predetermined which was the case in this study. (Tuomi and Sarajärvi 2002) More on the themes is explained in the interview process section.

In the figure 3 below, the process of how this research was conducted is depicted, with the green colour indicating the use of quantitative research methods and the blue colour referring to qualitative or mixed research methods. Data types utilized in different sections of this research, and their sources are categorized in more detail later in the section.

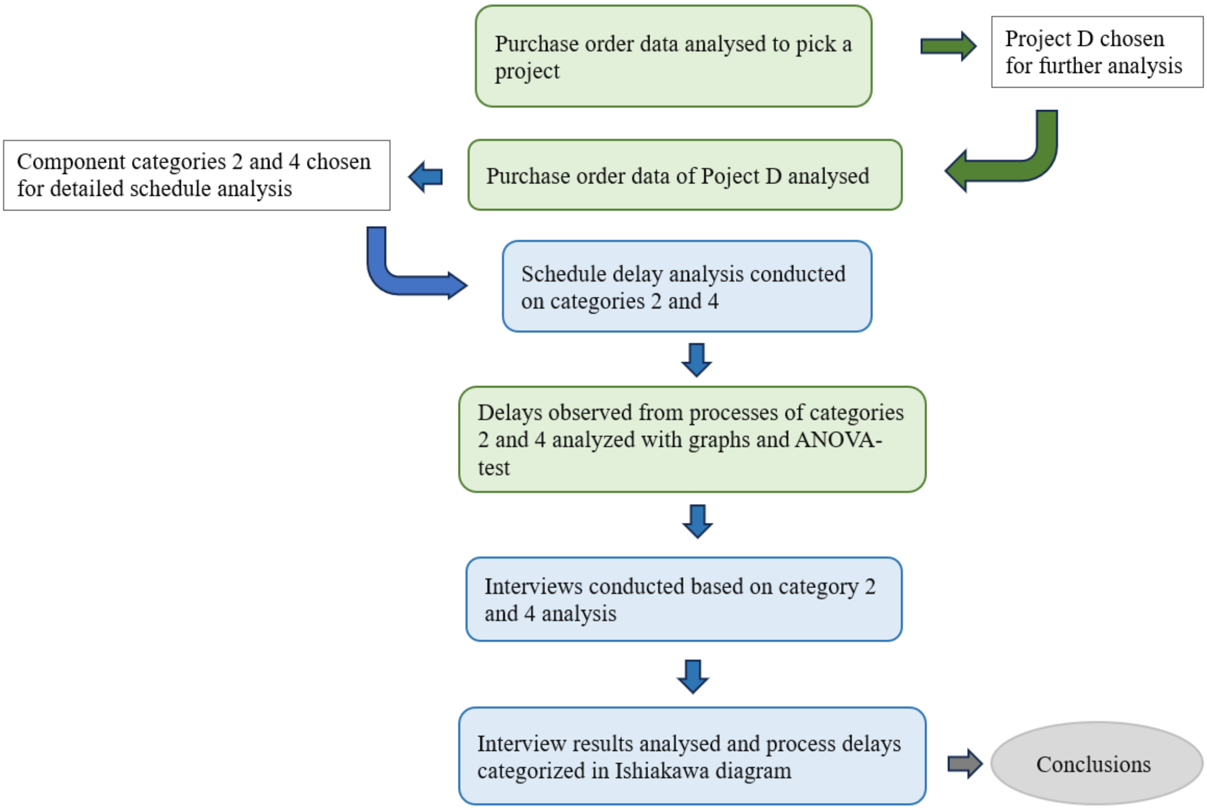

Figure 3 The research process

As is visible in figure 3, this research started with the analysis of this quantitative data, to help specify and limit the scope of a project that would be inspected. After choosing the project, a similar analysis of purchase order data was done to choose distinct component categories for further schedule analysis. The followed schedule analysis required information on many different sources, in type both quantitative and qualitative. The delays found through the schedule analysis were then analysed with scatter plot graphs and a one-way ANOVA- test in order to see if the component category influenced the severity of delays experienced in different processes. After the schedule analysis, interviews were conducted with people working in the case organization, after which the results were analysed and consolidated. In order to bring together the information found through both quantitative and qualitative data, an Ishikawa diagram was used to categorize information on schedule delays. Through interviews, it was possible to investigate research topics of communication of lead time information within departments and personal opinions regarding current processes, which could not be researched as thoroughly through numeric information. Qualitative content analysis was used to recognize and summarize relevant findings. Discussions relating to these topics results were also consolidated into process maps.

To conduct the research depicted in figure 3, many types of data from different sources were needed. In table 1 below, different types of data utilized in this thesis are categorized based on their type and source. Later on, when describing the conducted analysed, it is specified which data was used in that specific case.

Table 1 Data utilized in the research

Data	Source	Type
Purchase order data	ERP system	Quantitative
Summaries of purchase order data	BI Software	Quantitative
Lists of Product Notifications (PNs) by project	BI Software	Quantitative
Product Notifications	Engineering release software	Qualitative
Engineering schedules	Case organization’s project document database	Qualitative
Main schedule	Case organization’s project document database	Qualitative
Meeting notes	Case organization’s project document database	Qualitative
Insights from employees	Interviews	Qualitative

The qualitative data included different meeting notes, schedules, engineering releases (PNs) and insight of employees, which made it possible to gain more detailed knowledge on the scheduling matters beyond the numerical system data.

As mentioned earlier, this research started with a quantitative portion that aimed at defining the scope of the research. The intention of this analysis was to find a single project as a case example and within this project, pick component categories that could be analysed further.

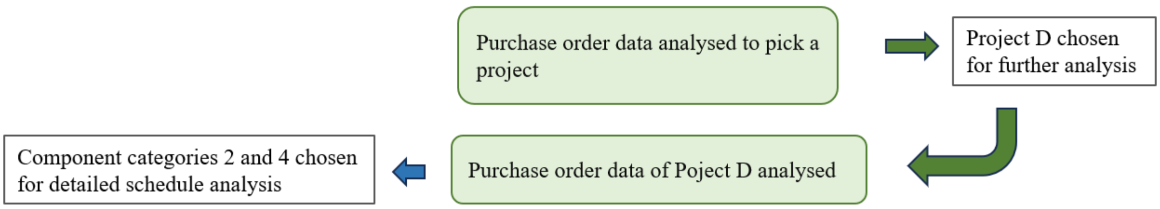

Figure 4 Initial quantitative data analysis

The data used in this analysis is depicted in the table 2 below. In order to scale down what project to choose for further analysis, there was analysis done to purchase order data that could be accessed through the company’s ERP system and summarized in reports. This purchase order data included, among various other metrics, order placement date and the wanted delivery date, price, order amount, and metrics relating to which project and structure the order belonged to.

Table 2 Data used in initial scaling

Data	Source	Type
Purchase order data	ERP system	Quantitative
Summaries of purchase order data	BI Software	Quantitative

The ERP system in question had been fully in use approximately for the last three years, which is why this timeframe was chosen for the purchase order data, which was then uploaded to Microsoft Excel. This data was sorted with the intention of finding correlations or consistencies when it came to, rush orders, product and component categories, and late deliveries within and between different projects. An order could be categorized as a rush order if the item had been ordered under the lead time that had been specified for that item in the ERP system. This scaling was done by utilizing a pivot table that summarized the number of purchase order lines of each project. Based on the number of lines categorized as rush orders, it was possible to calculate a rush order percentage for each project. A picture of this initial scaling can be seen in figure 5, in which due to confidentiality reasons the names of the projects have been changed.

Project	All purchases	Rush orders	Rush order%
Project A	8549	3520	41 %
Project B	5207	1975	38 %
Project C	6894	2504	36 %
Project D	10057	2796	28 %
Project E	30447	6321	21 %
Project F	8999	1851	21 %
Project G	12614	2529	20 %

Figure 5 Initial scaling of projects

In figure 5, the top seven projects are sorted according to their purchase order line and rush order line amounts. Highlighted in the figure is Project D, which was the project chosen for further analysis in this study. Project D was a machine rebuild project, with the customer located in EU area. The factors that influenced the decision to choose this project specifically, was the relevance, and short time since completion compared to other projects in the top seven, which would mean that the processes and practices would be the same as the ones currently used. It was also thought to be more likely that people would still remember details relating to said project due to its recency. Other defining attributes were the project type being relatively common, likewise the logistics arrangements. The project had a considerable amount of rush orders compared to the complete order amount and notable delays in delivery of some structures, which made it well suited for this research. The scope was focused on Project D and its purchases, that occurred during an approximately three-year time period.

The following research phase after choosing a project was to further analyse purchase order data of Project D, in order to find defined component categories, that could be taken into a more detailed scheduling process analysis. Further analysis of the data of Project D is presented in figure 6 where the purchase order lines of Project D are sorted with a pivot table in Microsoft Excel according to their activity descriptions and rush order percentages.

Activity description	Count of ActivityDesc	Share from all	All lines	Rush %
Category 1	649	23 %	1353	48 %
Category 2	503	18 %	1021	49 %
Category 3	469	16 %	1933	24 %
Category 4	388	14 %	865	45 %
Category 5	276	10 %	1485	19 %
Category 6	127	4 %	476	27 %
Category 7	82	3 %	251	33 %
Category 8	80	3 %	885	9 %
Category 9	77	3 %	118	65 %
Category 10	53	2 %	92	58 %
Category 11	32	1 %	532	6 %
Category 12	27	1 %	311	9 %
Category 13	22	1 %	151	15 %
Category 14	20	1 %	44	45 %
Category 15	18	1 %	121	15 %
Category 16	15	1 %	31	48 %
Category 17	8	0 %	229	3 %
Category 18	7	0 %	217	3 %
Category 19	2	0 %	5	40 %

Figure 6 Further scaling of Project D purchase orders

Rush order percentage was chosen as a categorizing variable in this analysis, since a high percentage within a component category could indicate a possibility of there being delays along the schedule, causing components to be ordered too late. Activity description in this analysis tells what main structure one specific item belongs to. Due to confidentiality reasons, the names of the product structure categories have been changed. Highlighted categories 2 and 4 were chosen into the detailed schedule delay analysis. Category 1 was not chosen due to the category including several structures manufactured outside of Europe which possibly could distort the accuracy of purchase and delivery dates found in the ERP system. Category 3 was not chosen due to the category including components belonging to several structures, and components which proved to be difficult to trace in the ERP system. Categories 2 and 4 were suitable subject based on the high rush order percentages, and high percentage of “share of all” which refers to how big of a part these categories make of all the project’s purchases. It was also taken into consideration, that these two structures are often also sold as singular projects, and in those instances, the project schedules are commonly stricter and less flexible, which highlights the importance of the scheduling process. Both Categories 2 and 4 are large mechanical structures that are typically either pre-assembled in the case organization's own workshops, after which they are sent to suppliers for final assembly or assembled from start to finish by suppliers.

After this research phase, the next step was to conduct schedule analysis, during which the processes of Categories 2 and 4 were mapped to find possible delays in different parts of the process, and in functions of departments involved in the process (LDP, Engineering, Procurement, and GP).

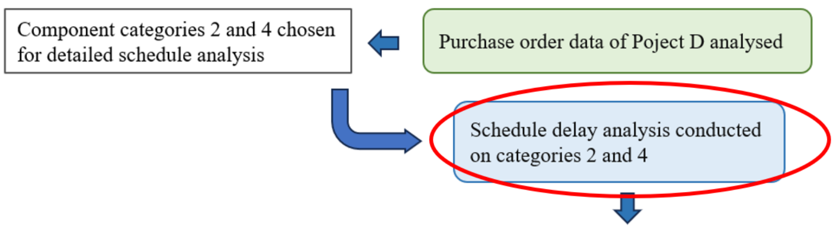

Figure 7 Schedule delays analysis-process

In order to conduct this analysis, data was brought together from various sources. This portion of the research combined quantitative and qualitative data types in the analysis. The specific data types utilized are shown in Table 3.

Table 3 Data used in the schedule analysis

Data	Source	Type
Purchase order data	ERP system	Quantitative
Summaries of purchase order data	BI Software	Quantitative
Lists of Product Notifications (PNs) by project	BI Software	Quantitative
Product Notifications	Engineering release software	Qualitative
Engineering schedules	Case organization's project document database	Qualitative
Main schedule	Case organization's project document database	Qualitative

Data for this part of the research came from engineering release notifications (PNs), purchase order data from the ERP system, List of PNs by project, and schedules from organizations own project database. Through bringing together information from different sources, it was possible to combine into a timeline the different starting times of different processes and calculate the differences of these dates to find out how long each action took. This way it was possible to find possible delays and map the processes starting from item release from engineering to the moment the structures were purchased and received in the ERP system. The mapped timeline and dates were compared to the corresponding dates and release points determined in project engineering schedules. By doing this it was possible to see if the days matched the ones presented in the project schedule, and overall see which functions in the process were delayed. Mapping the process also made it visible if delays in certain sections of the process led to delays in subsequent actions.

In one PN, it is common to release one structure or one assembly. Overall, the analysis included 13 PN releases of Category 2 and 26 PN releases of Category 4. For Category 2 this consists around 76 % of all released PNs of Category 2, and for Category 4 the same figure was 26 %. This affects the validity results, since analyzing only part of the PNs does not give comprehensive picture on amount of schedule delays overall in a category.

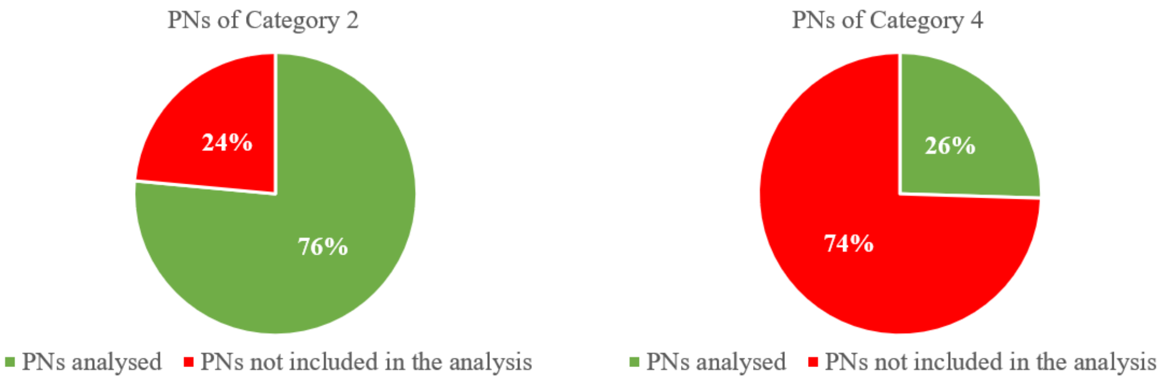

Figure 8 Percentage of PNs of Categories 2 and 4 included in the schedule analysis

As the overall PN release amount for Category 2 was significantly smaller, it was possible to analyze a larger proportion of PN. As the PN amounts were significantly larger for Category 4, the focus was directed to PNs that were issued for specified Long Lead Time Items and PNs that were published late. Some PNs were left out of the analysis due to it being difficult to connect the PN data to data from the ERP system. This was due to differences in component names or a very large number of components which made it difficult to trace which structure they were part of. This was common for some automation and electricity components. There were also some other PNs left out of the analysis due them considering warranty components that are not relevant from the scheduling viewpoint. Since the delays found through the schedule analysis were in numerical form, it was possible to analyze these results in timeline and scatter plot graphs, and to do one-way ANOVA-test, which are visible in the empirical section.

3.3 The interview process

After analyzing the delays, the next step was to conduct interviews. Interviews were chosen as a research method, due to among others, their characteristics of being able to access historical information from the participants (Creswell 2009, 179). The interviews were conducted as semi-structured interviews, in which instead of using the same predetermined structured questions with each interviewee, there were some priorly determined themes and key questions available if needed. In semi-structured interviews, depending on the person who is being interviewed, and the content of the responses, some questions can be modified or completely left out. Compared to structured interviews, there is also more room for free discussion. (Saunders et al. 2016) The interview questions were divided into overall four categories of “Scheduling process”, “Project related questions (Project D)”, “Sharing and utilization of intra-organizational information” and “Communication of information relating to lead times”. These themes and interview questions were determined according to the research questions and objectives, and also the theoretical background of the thesis. These categories were utilized in the qualitative content analysis, and the interview results that in their content fit these categories, were summarized.

As mentioned earlier, the participants for the interviews were chosen according to the results of the data analysis and the viewpoint of people working in managerial positions in other departments. The procurement personnel chosen were the ones specializing in Category 2 and 4 purchases, and during the interviews, examples relating to their own purchases were picked to be discussed from the schedule analysis. The people chosen from the LDP department were the ones responsible for processing and releasing the PNs included in the analysis, while the engineering personnel chosen for the interview were either in responsible for more elaborate scheduling in the department or had an otherwise advisory position. The person interviewed from the scheduling department (GP) was a person who had been making schedules for both Categories 2 and 4 for several years. When scheduling the interview with the participants, the duration of the interview was estimated to be from 30 minutes to an hour. Altogether there were eight interviews conducted and the eventual durations can be seen in table 4, along with the description of what department the interviewees were from.

Table 4 Summary of the interviews

	Duration	**Department/Category**
Interview 1	30 min	Procurement (Category 2)
Interview 2	32 min	LDP (Category 2)
Interview 3	26 min	Procurement (Category 2 and 4)
Interview 4	52 min	Global Planning
Interview 5	28 min	LDP (Category 4)
Interview 6	1h 24 min	Engineering (Category 4)
Interview 7	41 min	Procurement (Category 4)
Interview 8	28 min	Engineering (Category 2)

The overall explanations of the thesis and its background were provided for the participants before the interviews, along with the question form and the file including the schedule analysis. The interviews were conducted through Microsoft Teams and at the start of the interview, the topic of the research was explained once more, as well as the details of the schedule analysis. The interviewees were informed that the interview would be recorded and used for the purpose of the master’s thesis, but that their answers would be addressed as anonymous. It was also mentioned that the interviewees could provide additional information relating to the questions after the interview if needed. The interviews were conducted in Finnish and the interview questions were also provided in Finnish. All of the interview topics were covered with each interviewee, but due to the people working in different departments and with different tasks, some questions were left out for some participants, and in other instances, additional follow-up questions were provided. For instance, the last section of the interview concerned mostly the usage of Long Lead Time Excel, which was a document where procurement teams updated lead time information, but as the LDP department did not utilize the Excel file in their tasks, this section was not as thoroughly discussed in their interviews. After the interviews, the recordings were later transcribed, and the quotations used for this thesis were translated into English. The interview material was then analysed, and relevant points summarized. The full interview form is visible in the Appendix 1.

4 Empirical study

In this portion of the study, the results of the research are presented. The first section focuses on the interview results regarding the scheduling process and long lead time item (LLI) lead time information usage, which were summarized by creating a process map of the creation of the engineering schedule, and a detailed process description of utilization of information on LLIs between planning and procurement through an Excel file. After the process maps, Project D, and the results of the schedule analysis and one-way ANOVA test are presented. The delays that were evident in the scheduling process through the analysis and interviews are summarized in an Ishikawa diagram. Finally, the discussions that were had relating to information exchange on lead time changes and on a general level between departments, are summarized and an updated process on communication of LLI lead time information is presented.

4.1 Project scheduling process in the case organization

The first sub-question of the thesis was determined as “How is the current project scheduling process operated in the case company?” This topic was considered in the first part of the interview, which was more free in form and structure, and where the interviewees could openly describe their own role in the scheduling process and daily tasks relating to it. In these conversations, they could also bring up challenges or areas of improvement if needed. The answers of the interviewees were analysed by forming a general description of the scheduling process that is later depicted in figure 9.

In the case organization, the project scheduling process consists of several sub-processes and actors that are involved in different stages of the process. One of the key processes that defines the procurement schedule for items, is the creation of an “engineering schedule”. In the initial stages of this process, the inputs from procurement in the form of lead times are utilized to define the needed activity durations for items that have long lead times, or otherwise critical status. However, currently in the case organization, there is no complete visibility from the procurement department to other departments specifically to the scheduling department, on how the provided data is used, and procurement schedules created. It has been presented that there are risks associated with unsuccessful procurement scheduling such as item unavailability, and project and production delays (Dixit et al. 2014).

In the case company, the engineering schedules for Category 2 and Category 4 items are created by the Global Planning (GP) department, which is in most cases responsible for schedule creation. In some other product categories, the engineering department is responsible for the schedules. Before the actual engineering schedules are created, several steps have to be taken. One of these is the so-called purchasing review meetings, where participants come from different departments to discuss possible risks and otherwise noteworthy subjects and project particularities. These meetings and their dates are also defined in the schedules.

In order to start their process, schedule planners require information from different sources through which they are able to create schedules. These information inputs include the product split, main- and assembly schedule, which differs depending on the assembly location. Planners utilize templates that include built-in schedule models of the wanted structure, that bring data from servers. The template considers the different interdependencies and links between different phases and actions included in the scheduled process, and automatically times certain actions based on what information is changed. When the planner has completed the schedule, the interviewees mentioned that the schedule is usually sent to the responsible purchasing personnel and engineering department for final verification, before the initial release. It was also mentioned that the scheduling personnel are in contact with people from engineering and procurement often already in the scheduling phase, if they have uncertainty relating to for example product or component lead times.

Even though the scheduling model template inherently includes the activity start and finish dates, the schedule planner will need to go through each individual date and verify them based on the information they have available to them. As components and items with particularly long lead times or otherwise critical status have to be often released to purchase before the main structure, and all other components with shorter lead times in the same structure, they are displayed as their own separate lines in the schedule template. For these items, schedule planners look for lead time information from an Excel template that is maintained by the procurement department. The planners sort the view to see the wanted items and add the information to the schedule model.

The engineering schedules are not fixed, and possible changes are operated through schedule revisions. There are varying reasons why a schedule might have to be revised, but common occurrences are changes in the scope, product split, or in the location of the assembly or supplier. For instance, switching from a European supplier or manufacturer to a North American equivalent significantly prolongs the needed lead time. In a similar manner to schedule publication, revisions are shared on a wide distribution along the organization, and depending on the influence, the revisions are generally verified by needed people. Often, schedule changes relating to moving scheduled dates to earlier dates contain more risks and require attention and measures from various departments compared to moving the schedule forward.

However, every change to the schedule is not updated as a new revision, depending on if the change comes very close to the start of the assembly or otherwise in such a late stage that it is not significant anymore for all parties. In the interviews, it was mentioned that although there is no rule considering how far into the project completion process the schedules are updated, as a rule of thumb if the schedules are moved to earlier dates, they are always updated. If the schedule is moved forward to a later date, it depends on how early the change is made. If the change is made at a stage where most of the engineering and procurement for example is already done, it is not as significant. The planners in this sense highlighted the impact and importance of the change, since if every small change would be updated, they would not have time to do anything else. Also, since the more precise and detailed assembly schedules and requirement dates are managed through the ERP system, updating the engineering schedules late into the project, gives very little added value.

When the schedule is eventually released, the engineering department divides the work for their teams according to the engineering schedule, and the determined engineering release points. Engineers will release the product information according to the planned release points with Product Notifications (PN) to the LDP department who will export the data into the ERP system and into a format where the procurement personnel are able to start their own processes.

As in the case company, the LDP department is in charge of the local assembly schedule, LDP does not influence when certain structures are assembled or made, but it has influence on smaller detailed structures inside an assembly and the schedule when they are assembled or manufactured. Based on this information, the LDP exports data to the ERP system where according to the assembly schedules and item data, the MRP will distribute the singular items to be purchased by the procurement personnel with corresponding requirements and planned purchase dates.

This before-described engineering scheduling process is pictured in simplicity in figure 9 below, where a “Swimlane” process map has been created according to the interview discussions. The figure depicts not only the process, but also the responsibilities. Circles depict the start and end points of the process. The process pictured in the figure is relevant for Categories 2 and 4 and other structures where the schedules are created by the GP department. The swimlane chart in as a full image can be seen in the Appendix 2.

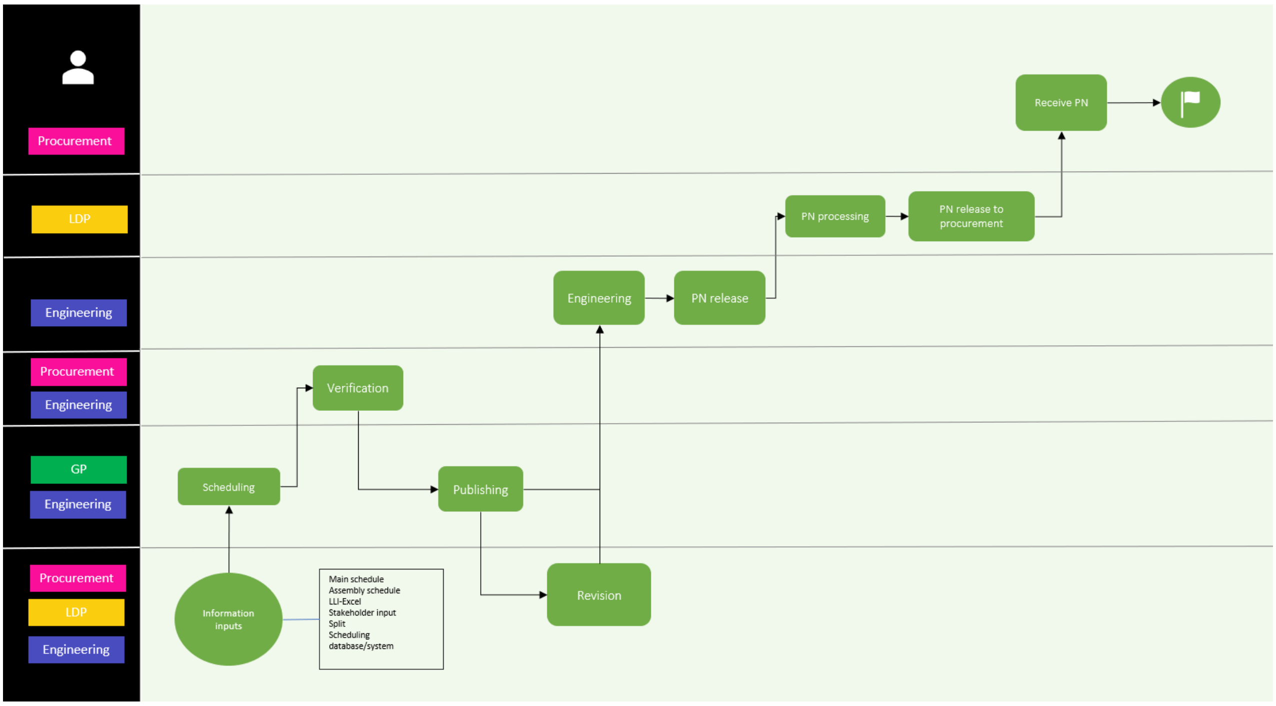

Figure 9 Engineering scheduling process (Categories 2 and 4)

4.2 Communicating lead time information between scheduling and procurement

In the chapter before, the scheduling process was examined on a general level. An important aspect of this thesis relates however to one inner process of the so-called “main process” and more specifically to the “information inputs” depicted in the beginning phase of figure 9. By clarifying this process, research questions 1 and 3 can be addressed. Regarding the information inputs, the purpose of this thesis was to investigate the mentioned Excel file used to maintain lead times of LLI, and the process and responsibilities relating to its use in the GP and procurement department. Clarifying how the Excel file is used by different departments, how people view its use, and if they feel it should be utilized differently, was investigated in the last proportion of the interview. Based on the interview discussions about the Excel file, together with earlier discussions on the general process and general viewpoints, a model of the previous process is formed and presented in figure 10. Later in the discussions, a proposition of a new process based on the research is presented.

As mentioned earlier, in order to determine accurate timelines for items and components with particularly long lead times or otherwise critical status, schedule planners utilize a Microsoft Excel file maintained by the procurement departments. The file includes the name of the component, its product area, names of common suppliers, lead time estimate, additional information, the date when the lead time has been checked, and the name of the purchaser who has updated or checked the lead time previously. The lead time estimate is in the file referred to as “purchasing time”, and it includes the internal lead time plus the delivery time.

The previous process of utilizing the Excel file began from an impulse that was given to procurement teams to check the lead times in the file and update them if needed. This impulse had not been regular and had come either from a request of the GP or from the management level. Following the request, purchasers checked items relevant to them, and if needed, updated the lead times. In the old file, there was only a column where purchasers could write down the date when the lead times were checked. This date did not indicate whether or not there had been updates made to the lead time or if it had remained the same after the check. After updating lead times, the updated version of the Excel would be published to GP and others from engineering and sales, who also sometimes require this information in their tasks. If schedule planners see that there have been updates made to the lead times, this information will be updated to all relevant ongoing or upcoming schedules. This simplified process is depicted in below figure 10.

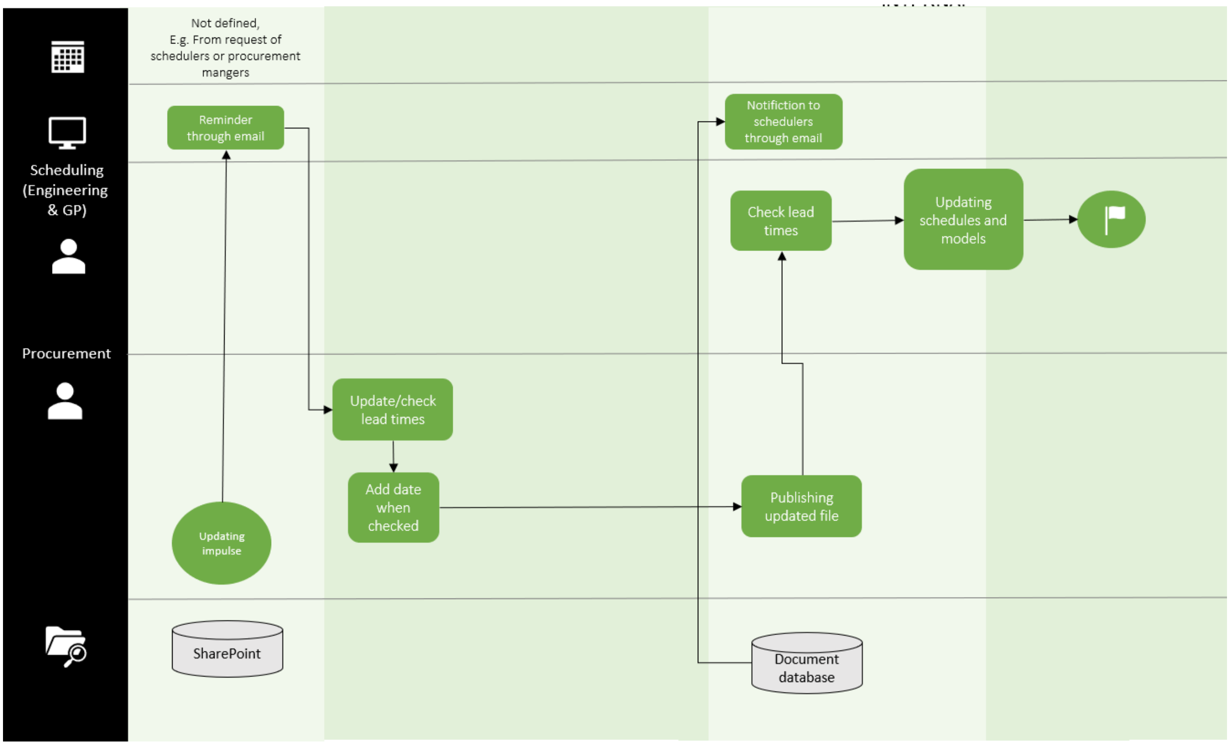

Figure 10 Previous process of updating lead time date information

In the old process, other departments did not have direct access to the actual file that procurement departments updated, but only to the published copy. After a new version of the file was published, scheduling personnel would review the file, sort the view for data relevant to their schedules, and see if there were any updated lead times. As mentioned earlier the "date checked" column in the old file did not tell if there had been any actual changes made to the lead times, or if they had only been checked. This meant the schedule planners had to check every relevant line in the file, and either compare them to previous schedules, their own lists, or ask directly from purchasers if anything had actually changed. This caused a lot of confusion and additional work for schedule planners. This factor was also pointed out by the schedule planner in Interview 4, who commented on the old template and its use by saying that there was a feeling the current usage of the file had not been "genuine". The interviewees from the engineering and schedule planning department also commented on the old file by doubting its trustworthiness, as the "dates checked" for some items were many years in the past. Due to these uncertainties regarding the file, it sometimes was said to be easier rather to ask someone, than use the file.

The schedule planner stated strongly, that if there were actual changes in the lead times, it should be marked clearly for planners, so they would be able to precisely know what had been changed and when. For the scheduling personnel, it was said to be important to know immediately if something has been changed, so that the new lead times could be updated to upcoming and ongoing schedules as quickly as possible, making it more likely that it is still possible to react to the changes.

There have been intentions in the case organizations to update this process and clarify the responsibilities related to the lead time updating process. While conducting this research, an effort was made to update the structure of the Excel file, based on the propositions of the planning department and others using the file. Based on the comments, there were altogether three new columns added to the file to make it easier to use. The old *"*Lead time checked*"* column was split into "checked" and "updated" columns to clarify the difference between checking and updating the lead times. This way, it would be easier for the scheduling department to see which dates they would need to update to the scheduling models. There were also two new columns added to be updated by Global Planning, "Implemented in model schedules (date)" and "By whom", in which schedulers after checking the file could add the date when they have implemented a lead time from the Excel file to the schedule and add their own name. This way, it was possible to see if the latest information had been updated to the relevant models. However, even after the update, there still were uncertainties relating to the customs and responsibilities of the LLI lead time updating process.

The interviewee from GP commented that the most prominent issue with the file had to do with the updating convention and the lack of an "updated" column, but there were also instances where the current formatting was not ideal and possibly could be developed regarding the current product area categorization, which was said to be a bit too broad and vague in some cases. Similar comments on the vagueness of the categorization were also given by the engineering personnel, but overall, despite some of the lacks, the interviewees viewed the previous Excel file as generally working. It was seen the most important for schedulers that the information on the lead times would be recent and accurate, since for them, it is a priority to get information on changed lead times as soon as possible.

When it came to the procurement personnel who are responsible for updating the lead times to the Excel file, they all agreed that for them, updating and checking the different lead times is not particularly time-consuming or difficult. The only issue was said to be that they might forget to do it, since at the moment, there is no agreed schedule on when to check the accuracy of the lead times. When asked the interviewees from the procurement department about the variability of lead times and how often they think the lead times in the Excel should be checked, the answers varied from “once a year” to “once in a quarter”.

4.3 Project D schedule delay analysis and ANOVA test

In the earlier sections, simplified versions of the case organization’s scheduling process were presented. However, as unexpected situations can occur, hindrances along the different phases of the process in everyday operations might appear. As noted in the methodology chapter, schedule analysis was conducted on some structures of Category 2 and 4 of Project D, by combining data from multiple sources. In Figure 11 there is presented an example from schedule analysis that was done with Microsoft Excel.

	1. 25.3.2022	Structure A					
PN from start	3. 4	Purchase	4. 30.5.2022		Receipt	5. 4.11.2022	6. 20.1.2023
	LDP4w 9.	Lead Time	7. 23		Actual	8. 34	
	PRO5w 10.	**Start**	2. **25.2.2022**		**Finish**	11. **28.10.2022**	
		Purchase from start	12. 13		Weeks from finish	13. 1	14. 12

Figure 11 Screenshot from the schedule analysis (Structure A, Category 4)

An in-depth explanation of how to read the results and what different values present, is explained in table 5, where the numbers correspond to the blue numbers in figure 11. In figure 11, the red coloring in the font indicates a delay from the schedule, whereas the green color in the font refers to being ahead of the schedule. For example, “Weeks from finish” is marked as red 1, meaning the planned receipt date of Structure A was one week later than the “Finish” -date, which is presented in the engineering schedule as 28.10.2022.

Table 5 Explanation of the values of the analysis presented in Figure 11

1	PN release date
2	The planned release date for the PN in the engineering schedule
3	Difference between the planned and actual PN release date in weeks
4	Date when the item was purchased in the ERP system
5	The original planned receipt date of the item in the ERP system
6	When the item was actually received according to the ERP system
7	The planned lead time (difference between original planned receipt date and order date in weeks)
8	The actual lead time (difference between the actual receipt date and order date in weeks)
9	How long it took LDP to process the PN from engineering to procurement in weeks (LDP1w = the PN was processed in 1-7 days)
10	How long after receiving the PN was the purchase done in the ERP system in weeks
11	Finish date in the engineering schedule of when the items should be received
12	Difference between the item purchase date in the ERP system compared to the engineering schedule start date in weeks
13	Difference between the original planned receipt date compared to the finish date in the engineering schedule in weeks
14	Difference between the actual receipt date compared to the finish date in the engineering schedule in weeks

Based on the start and finish dates of operations, it was possible to map a timeline of the structure and when comparing the actually occurred process to the planned schedule, find delays. As the figure 11 is complicated to read, in figure 12 the same data is depicted as a timeline graph. On the top side of the graph, the actual process is depicted while the bottom half of the graph shows the process timeline in a way that was planned according to the engineering schedule. In the timeline, the abbreviation ENG refers to engineering, and PRO to procurement. In the upper section, the PN start date is marked according to the actual PN release date, and in the lower fraction, the PN start date refers to the date mentioned in the original engineering schedule.

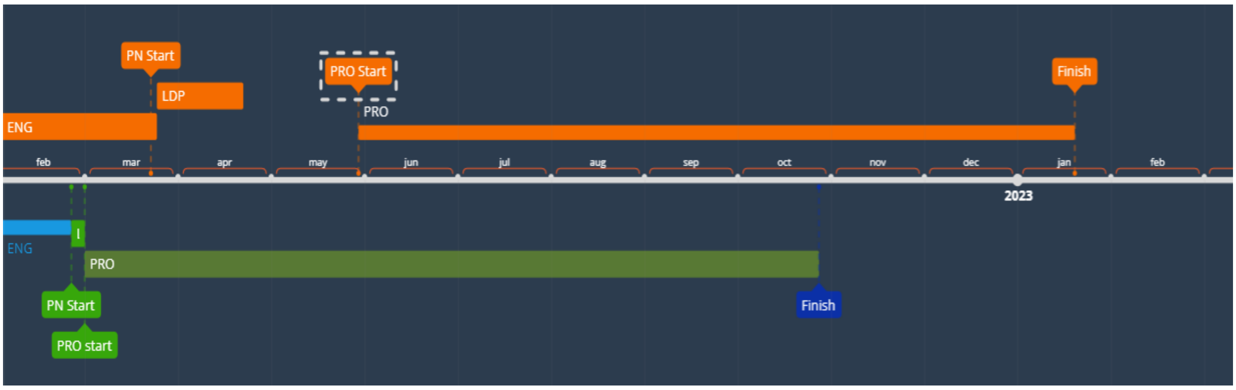

Figure 12 Timeline of Structure A (Category 2) from the engineering release to purchase and receipt

As can be seen more clearly in the timeline figure, in the case of Structure A, all of the processes experienced delays, and started later compared to the original planned schedule. Another example can be seen in figure 13, where the largest delays came from the LDP processes, and from the long procurement line can be seen that the order lead time has been much longer than expected.

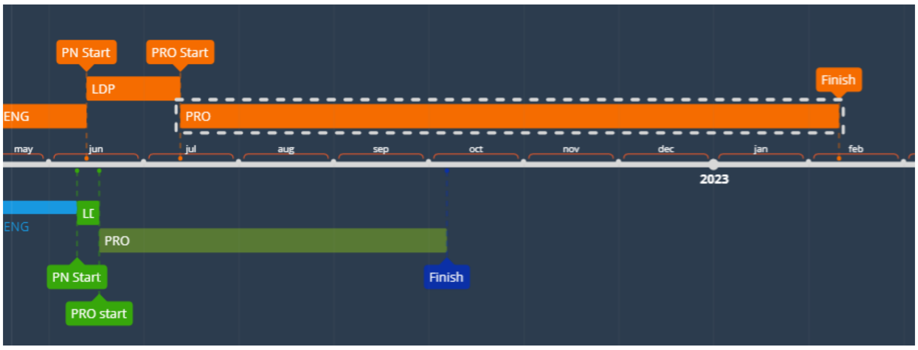

Figure 13 Example timeline of Category 4 structure

Overall, from the 39 structures released in PNs that were investigates in the schedule analysis, 29 were delivered late for more than two weeks compared to the finish date specified in the engineering schedule. This is depicted as a scatter plot in figure 14. In the interviews however, it was mentioned that in most cases where in the analysis an item had been late compared to the finish date of the schedule, it had not caused significant issues or been the main reason why the assembly had been late.

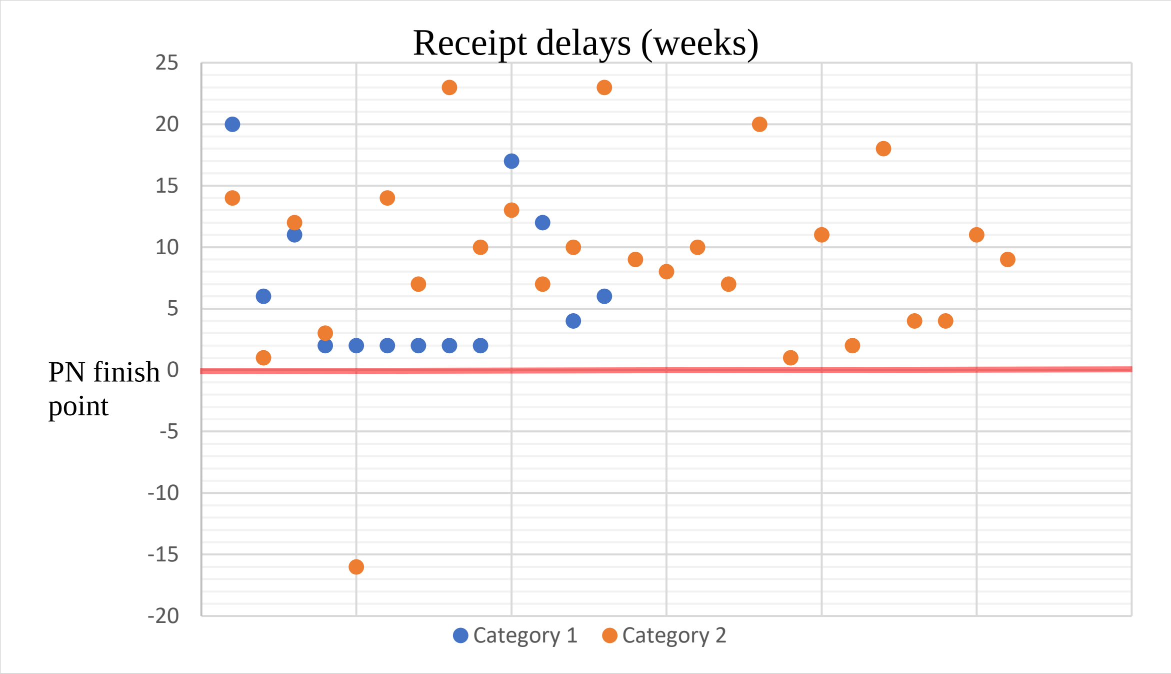

Figure 14 Scatter plot of receipts compared to engineering schedule finish dates

Regarding the delays that had occurred in the engineering phase visible from the PN release dates, 21 out of the 39 were published more than one week late. This is visible from the scatter plot in figure 15. When comparing the two categories, from Category 4, 17 PNs were published late from the altogether 26, and four PNs from Category 2 from the altogether 13.

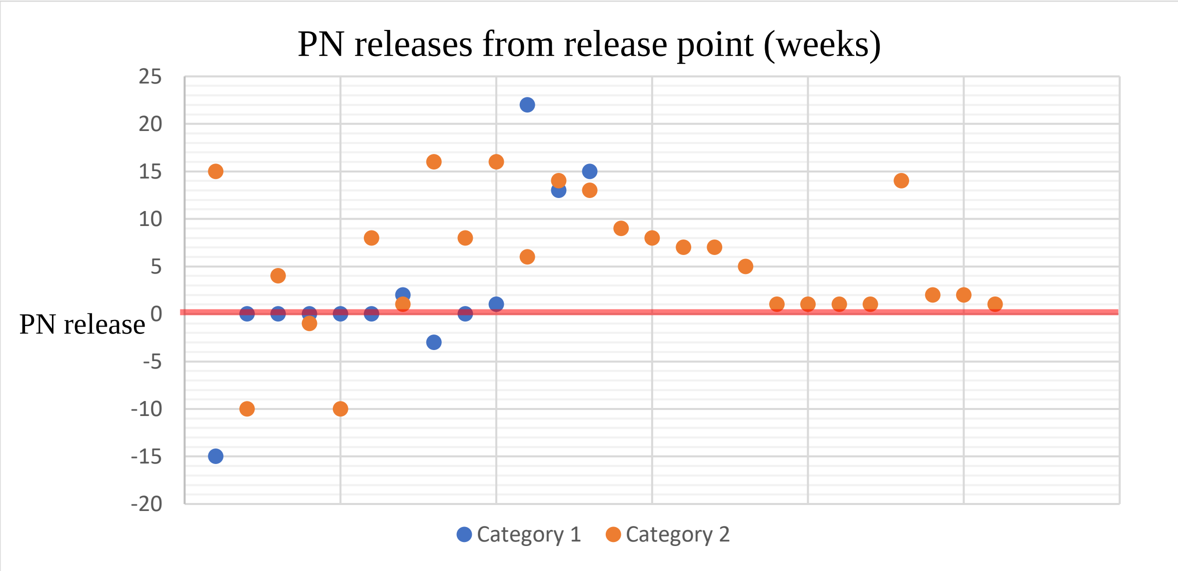

Figure 15 Delays of engineering scatter plot

In figure 16, the LDP process times are depicted in a scatter plot, where the red line is set to six days, which is the target process time for the department. As can be seen from the picture, most of the PNs were processes in six days or less, with the exception of six PNs that had significantly longer process times.

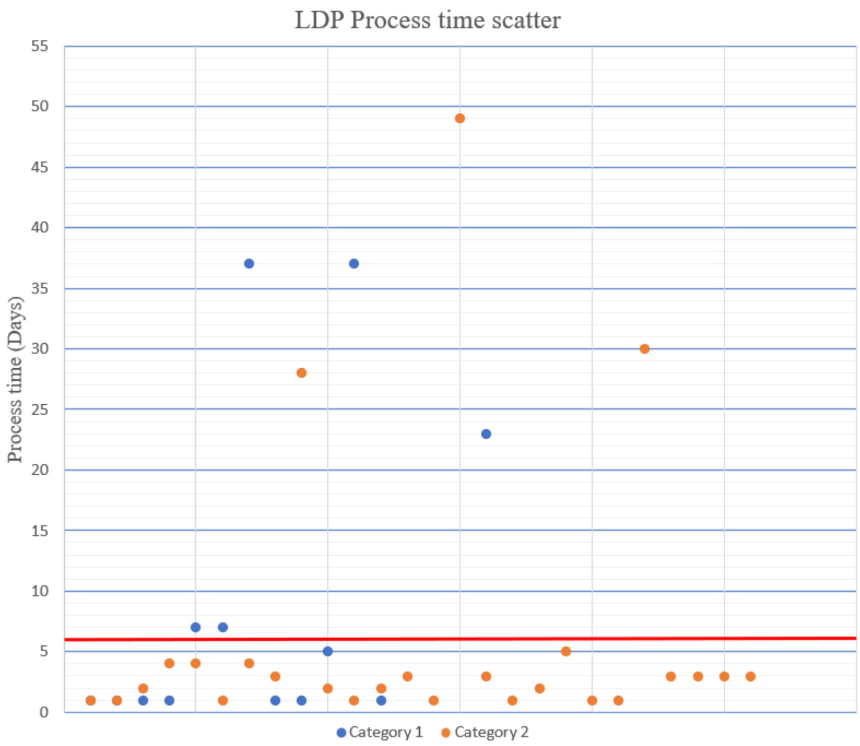

Figure 16 LDP process time scatter plot

The time between procurement receiving the PN and placing the purchase in the ERP system are visible as such in figure 17. Since there is no historical data available in the ERP system on the dates when the MRP had asked these items to be bought, it cannot be definitely determined if the purchase action has been delayed. Because of this, this information was not analyzed with one-way ANOVA- test.

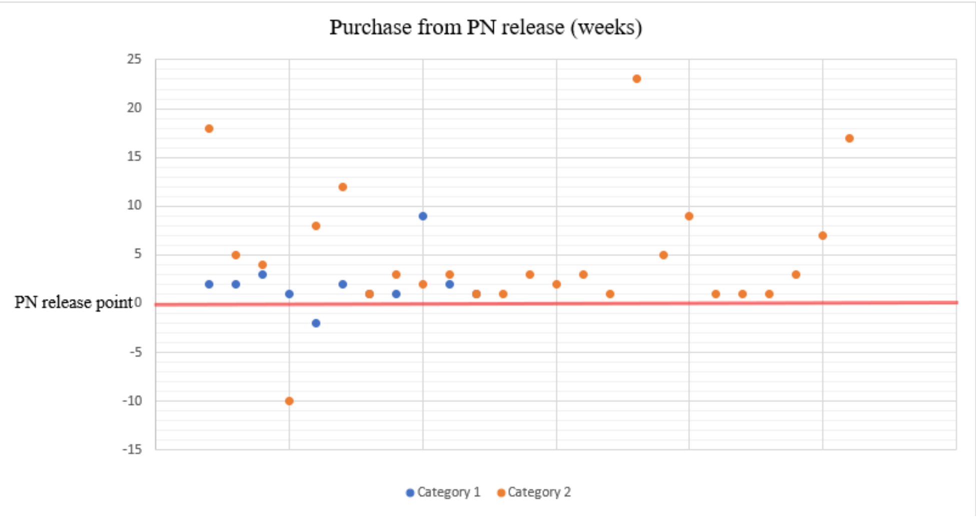

Figure 17 Purchase action compared to the PN release

The data depicted in figures 14, 15 and 16 was tested with one-way ANOVA variance tests, to see if there were any statistically significant differences between the averages of categories 2 and 4, when it came to delays or the length of processing time. Difference in the averages would indicate differences in the length of delay, or process time that the category has an effect on.

H_0: No difference in the averages of Categories 2 and 4

H_a: Averages of Categories 2 and 4 are different

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	61,03846	1	61,03846	1,00793	0,32192	4,105456
Within Groups	2240,654	37	60,55821			
Total	2301,692	38				

Figure 18 Delays of engineering ANOVA test

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	92,62821	1	92,62821	0,625265	0,434137	4,105456
Within Groups	5481,269	37	148,1424			
Total	5573,897	38				

Figure 19 Length of LDP process time ANOVA test

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	44,62820513	1	44,62821	0,804986	0,375408	4,105456
Within Groups	2051,269231	37	55,43971			
Total	2095,897436	38				

Figure 20 Delays of receipt ANOVA test

When it came to the ANOVA test, it can be seen from each figure 18, 19, and 20, that in every instance, the p-value was above the 0.05 threshold value, meaning that the null hypothesis stays valid. In all of the cases the F-value is also smaller than the F crit-value which aligns with the null hypothesis staying valid. This means that there was no statistical difference between the two categories, and it can be concluded that the category of the component did not have any statistical significance to the amount of delay or process time, in the cases that were analysed. It however should be noted that the sample size of instances included was very small, under 30 in each category, which weakens the validity.

4.4 Interview insights on schedule delays

In order to investigate the delays depicted with the schedule analysis in the previous section in-depth, the Project D was discussed during the interviews. The intention was to find if there were any instances where the process did not go as planned, and what were the causes of delays that came up in the schedule analysis.

As research questions 1 and 3 considered the possible risks, inefficiencies, and role of procurement as a support in the scheduling process, by examining the delays that were present in Project D, it is possible to see, if the delays were caused or affected by the scheduling process or more distinctly by the process associated with use of the Excel file used to communicate LLI lead time information. This way, it was possible to examine if there were instances where procurement could better support other departments or help solve these instances as mentioned in the research question 1 and 3.

During the interviews, Project D was discussed in the first part of the interview through the individual cases that came up in the schedule analysis, and more specifically if they could point out factors that caused the delays that were presented, but the interviewees were also given the possibility to comment freely on Project D and their own processes relating to said project. In some instances, if the interviewees were unable to remember or give reasons for the distinct cases of Project D, they commented on a general level what usually caused delays in their operations. Based on the results, these factors were summarised using the Ishikawa diagram under five categories of "Product", "Organizational environment", "External environment", "Timing", and "Methods". The fishbone diagram is visible below figure 21, with the full picture visible in Appendix 3. The most notable categories that came up in all of the interviews were the categories of "External environment", "Product" and "Organizational environment".

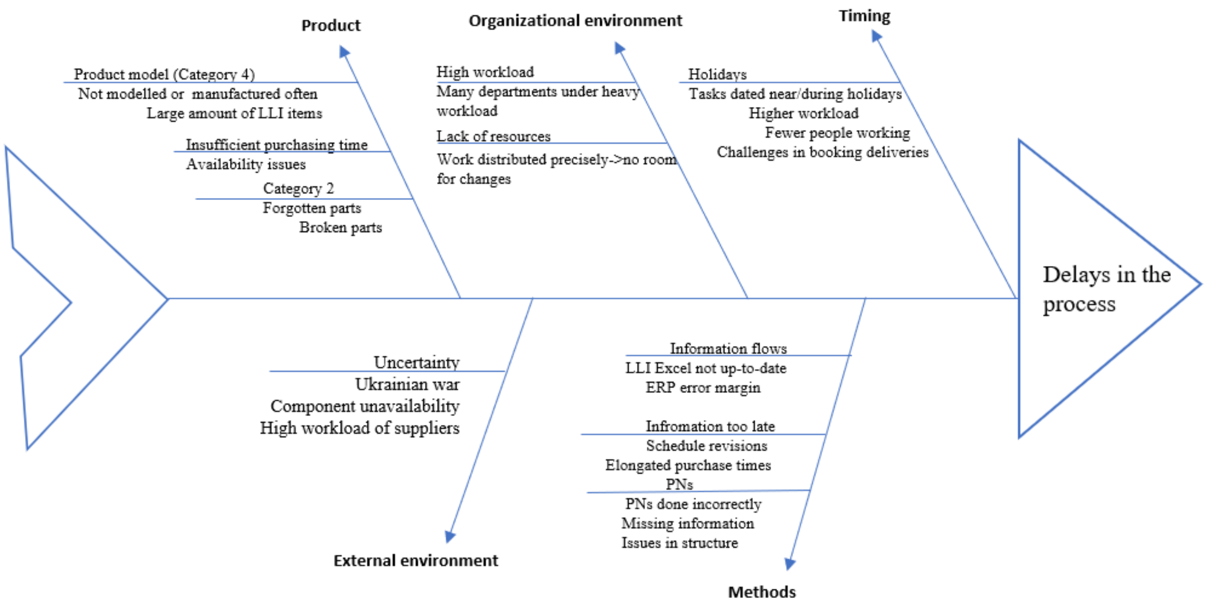

Figure 21 Categorization of causes of delay in the processes of Project D

When discussing with the interviewees about Project D and the case examples shown from the analysis, there was one common theme that came up in all of the interviews as a factor that negatively affected the process. This was the sudden and drastic increases in lead times of certain components and issues in availability, which were caused by the prevalent global situation at that time. The war that started in Ukraine at the beginning of 2022 significantly raised prizes and item lead times globally, complicated logistics chains, and suppliers had difficulties in accessing components and materials. For instance, the person from Interview 1 commented on the topic of component unavailability and shortages as such:

> *"Yes, there is nowadays (a lot of it), when the war started, we had shortages in electric components and we have had situations in many other assemblies as well (besides Project D) that we have the assembly mechanically ready, but*

> *we do not have these components that we would need to do tests with these devices.''*

Challenges in component availability were also brought up by the LDP department who mentioned that the seriousness of the issues was in a way not prepared for, since it came so suddenly. In the during the Interview 5, the participant commented as such on the topic:

> *''If you think for example a year backward, certain components were very challenging to get like all electric components and such. For example, last year in the spring it took us by a surprise little bit when these delivery challenges started appearing. The situation was such that we had already assemblies ongoing, and then it turned out that well, we are not getting these components like we thought.''*

The issue of component availability came up, especially regarding the Category 4 structure, where several components had significant issues in availability. It was mentioned likewise by both the engineer and the procurement personnel that one factor why the component availability caused such issues, and why the effect was particularly strong in the Category 4 structure, was due to the model of the product that was sold. This model happened to be of the sort that had not been manufactured often before, and also unfortunately happened to have a lot of automation and electric components that had long delivery times. As these specific components caused long delays in the assembly phases, the shorter delays in other structures and components lost most of their significance.

The global business environment also affected the purchases in Category 2, which experienced similar issues with components, especially relating to automation and electricity. An interviewee from the procurement department in Interview 3 explained the 12-week delay for Structure A, which is also depicted in figures 11 and 12, was caused mainly by delays of the supplier. It was mentioned that a supplier being behind schedule was common due to suppliers having a very high load in the economic boom a couple of years ago. In the specific case in figures 11 and 12, this was also the case, with the addition of there being a great difficulty to arrange transportation at the end of the year from central Europe to Finland. However, despite the 12-week delay compared to the engineering schedule, and the order being late according to the ERP system, the interviewee mentioned that the structure came well in time for the assembly.

As mentioned earlier and can be seen from figure 15, when it comes to Category 4, a significant portion of the PNs were registered as coming late from engineering. One significant factor behind the high number of late PNs can be found when looking at the revision history of the engineering schedules that determine the release points for the PNs. For the analysis of this thesis, the release dates were taken from the latest schedule revision that was published on the 20th of June 2022. Compared to the previous revision that was published on the 28th of March 2022, several changes were made in the schedule most of which related to increasing purchase times and adding time for the warehousing and LDP department. As the finish dates are determined in the sales phases and are largely unchangeable, the needed time for other activities is commonly taken by shortening the engineering phase, since it is one of the earliest processes. For example, in figure 22 it can be seen that in the newest revision, the start and PN release date was determined as 24.6.2022, while in the previous revision, the same date was 9.9.2022. When considering that the late revision was published on 20.6.2022, it can be seen that in this instance there were only four days to react to this 11-week change. When discussing this with the engineering department in Interview 6 about this change, it was brought up that since in most instances this update came so suddenly and without any warning, it was impossible for the engineering department to answer the update, and some of the releases were done according to the earlier version of the schedule. The engineer in interview 6 commented on the topic as such:

> *"There still is the original date (start date from previous revision) because I cannot precisely remember now what time in the world this came, but for me at least, if I remember correctly, I had no chance to make it earlier to the new date, so it was written down as late and a fair amount. We were given four days to do this sort of change which is completely impossible to execute…and you could imagine that if a thing like this comes four days earlier and people have their hands full of work and summer holidays are coming up, and the workload already scheduled so that the engineering would be done after the holidays, mission impossible."*

It was also brought up that this schedule update was done not only for Project D but for all ongoing and upcoming projects at the time. This decision was made due to the overall global situation which required longer purchasing times, and also the organization having an overall very heavy load which caused many of the departments to be under a lot of pressure and heavy workload.

	26.9.2022	Structure B					
PN from start	13	Purchase	29.9.2022		Receipt	9.12.2022	**24.3.2023**
	LDP1w	Lead Time	10		Actual	25	
	PRO1w	**Start**	**24.6.2022**		**Finish**	**14.10.2022**	
		Purchase from start	14		Weeks late from finish	8	23

Figure 22 Screenshot from the schedule analysis (Structure B, Category 4)

Another example of the effect of the update can be seen in figure 23, where the updated start date of 26.8.2022 was in the previous version 16.9.2022. In Interview 6 with the engineering personnel, it was mentioned that schedule updates themselves are not an issue, but how well the engineering can respond to these changes and rearrange their resources, is directly proportional to how early the information on the new schedule is received. This means that even drastic changes can be done with very few issues if the information on these is received early, versus a situation where changes are done in a very limited time frame. Due to many projects ongoing at the same time, and resources divided precisely between the engineering personnel within a team, it usually can be very difficult to rearrange the resources again at a later stage. Interviewee 6 commented on the topic of schedule changes a such:

> *"A two-week cutback is of the sort that it will not necessarily work unless there is substituting resources available. I mean that they do cause hindrance, but as I mentioned earlier, the earlier these sorts of changes come, the easier they are to manage."*

	12.10.2022	Structure C					
PN from start	7	Purchase	13.10.2022		Receipt	3.3.2023	**3.4.2023**
	LDP1w	Lead Time	20		Actual	25	
	PRO1w	**Start**	**26.8.2022**		**Finish**	**10.2.2023**	
		Puchase from start	7		Weeks from finish	3	7

Figure 23 Screenshot from the schedule analysis (Structure C, Category 4)

When interviewing the procurement personnel in Interview 7 regarding the example in figure 23, it was asked if it would have helped to deliver Structure C on time, if the PN had been published according to the revised start date of 26.8.2022, since both the PN and purchase order had been 7 weeks late. The procurement personnel answered that “it probably would have helped, but since other components were late so much it did not matter.”

As was depicted in the figure 16, from all of the PNs analysed, in 7 out of 39 cases, the LDP process times were longer than one week. As mentioned earlier, the target process time for LDP is 6 working days. When interviewing people from the LDP department on the delays that had occurred during Project D, the interviewees were not able to provide an exact answer to what had happened in the particular cases but told on a general level what could cause delays and hindrance to their processes.

In figure 24 there is presented an example where the PN was published according to the schedule, but the LDP process time was around five weeks. When discussing the topic with the LDP personnel responsible for processing the PNs of Category 4, there was no singular explanation why this was, but there were factors brought up that as combined could have caused the delay. In both interviews with LDP, it was brought up that most of the PNs with long processing times were published either near or during the summer holidays, which may have caused the PN to be processed only after the holidays. They also mentioned that it is common for there to be a larger influx of PNs before the summer holiday season, which can cause delays, as only a few people are handling all of the workload. It was also explained that around two years ago the LDP department had a heavy workload which caused the processing times to be significantly longer than those of today.

	20.6.2022	Structure D						
PN form start	0	Purchase	7.8.2022		Receipt	1.12.2022	**22.2.2023**	
	LPD5w	Lead time	17		Actual	28		
	PRO2w	**Start**	**20.6.2022**		**Finish**	**9.12.2022**		
		Purchase from start	7		Weeks from finish	1	11	

Figure 24 Screenshot from the schedule analysis (Structure D, Category 2)

Other reasons for possible delays were said to be caused by PNs that came from engineering incorrectly made, with missing information, or otherwise had issues in the structure which can make the PN impossible to process. These instances were said to often require cooperation between engineers and procurement personnel to get the PNs into a form where they could be published forward, which could take some time. This came up in regard to Category 2, with the LPD personnel commenting that the structure of the Category 2 product does not always support the way in which it is purchased, which is why there sometimes needs to be communication with the designated procurement personnel on how they want the parts to be released to the ERP system.

> *"If you think about Category 2, the structure can be such that it does not support the way it is bought, that sometimes you have to go through it with procurement what level they want to buy, do they want a lot of smaller parts or do they want to buy one level higher so that they buy the whole thing on only one order line.*

4.5 Sharing and utilizing intra-organizational information

After examining the scheduling process and the schedule delays that had occurred in Project D, topics of information sharing between different departments were discussed in the second part of the interview. The second part of the interview was more structured, and the questions concerned how information is shared between different departments, and what this information exchange was like relating to information on lead times and changes in the schedules. The interviewees were also able to express their opinions in general about the communication between different departments and if they saw ways in which this could be developed in the future. These discussions gave insights for the research questions 1 and 3.

When discussing topics relating to the scheduling process and overall, how procurement could better support the scheduling process, many interviewees did not have straightforward answers or propositions on what the procurement department could do better. Participants most often brought up processes and conventions they already saw as working and successful, for example, the engineer in Interview 6 mentioned the current practice of purchase reviews and other meetings in the early stages of the project, as a good convention where there is a possibility to examine the particularities of the upcoming project and items that have long lead times, or can otherwise be seen as having high risks.

Most drastic differences however could be seen when looking at the comments on the topic of communication on lead time information especially relating to sudden lead time changes.

The procurement personnel commented that it was important to them to communicate and inform project managers, production personnel, and other needed stakeholders if there were sudden changes in lead times or delivery challenges appeared. They also brought there being active communication between procurement personnel and the assembly of the organization when they in reality require different parts.

However, there were some more serious comments brought up by the engineering departments, when it came to discussing how in their viewpoint the sudden changes in lead times are communicated from the side of procurement departments. In the comments of interviewees, it appeared that often when talking about a drastic change in the lead time, this information came too late for them to be able to react properly. For instance, in the interview 8 the engineer commented as such.

> *"In my opinion, actually one of the biggest issues in the whole current process, is that purchase monitoring is missing almost completely. It is not monitored. I mean for example, today we purchase (an item) and then it is said that the delivery time is four months, well within those four months the supplier is not monitored if they can stay in schedule or not. Then only after four months when the order was supposed to be received, then it is stated that "well the delivery time will not work out", but in that point, it is too late. We cannot do anything at that point anymore. I mean that the purchase order monitoring is missing, or at least I myself have that kind of impression that it is missing almost completely in this organization of ours."*

> *" It would be important to get the information in the earliest stage possible to be able to react to it. And of course, this is not the task of engineering but rather some other department should handle the monitoring."*

Similar comments were given by the engineer in the interview 6.

> *If there is a situation where delivery times are suddenly increasing, in those cases usually there comes an email from procurement that the situation is like this now, and principally these emails come too late. This is because the specific item has already been ordered and the reception date has been confirmed by the supplier, and then the order is awaited, and then nearer to the reception date, information comes suddenly that this will not work out, and*

the supplier just states a new delivery date. At this point, we might have already many of those same items ready to be bought.

Besides comments regarding the information sharing relating to lead times, interviewees also had opinions regarding the general information sharing between departments. In Interview 2 with the LDP engineer, during the free discussion at the end of the interview, there was a comment made regarding increasing the communication between LDP and procurement departments. In the opinion of the interviewee, it would be good for LDP and procurement to have some sort of monthly meeting. The reasoning for this was that the interviewee felt like there might be some instances where feedback is not conveyed between the departments smoothly.

> *"I have a feeling that if there is something that we do (in LDP) that does not go exactly in the intended way (from the viewpoint of procurement), I get the feeling that it does not even come to our attention at all. In that sense, it would not do any harm to have a joint meeting".*

Later it was also added that having a joint meeting could also increase knowledge of the responsibilities of each department.

> *"I think it is not (always) completely clear when things have something to do with us and when it is the responsibility of Global Planning, and I think going through these sorts of things together would improve cooperation."*

The other LDP engineer in Interview 5, also agreed that having an active information flow between the procurement and LDP department is important. The interviewee mentioned that even though currently there is daily interaction between these teams, there could be more communication and information sharing especially in a situation where there are changes in the item lead times and procurement schedules.

> *"Surely there should be more. If there is a situation where some components require longer purchase times, these things should be addressed together with procurement, LDP, and engineering, so that we could update the correct lead times and items to the model structures.*"

The possibility of clarifying the responsibilities of different departments by increasing communication was also brought up in Interview 3 with a procurement team member. The participant answered a question if the responsibilities are clear between different departments and if there should be increased communication.

> *"No, I do not necessarily think it is (clear) and of course, it always broadens (perspective) when it is reminded who does what and how things are done. In the instructions, it is often mentioned that some operation does something, but it is not specified who within the operations does what."*

4.6 Updated process map for long lead time information communication

Based on a mapping of the previous process, and the insights gained from this research, a new process map was created to describe the process of updating lead time data into the engineering schedules. Compared to the old process that is depicted in figure 10, it was important to clearly define the responsibilities and the actions that are required from each department in each phase. This sub-process of the main scheduling process is depicted as a "swimlane" chart in figure 25. The main updates made to the process consider the impulses during the process and describing in detail what information each department enters into the file.

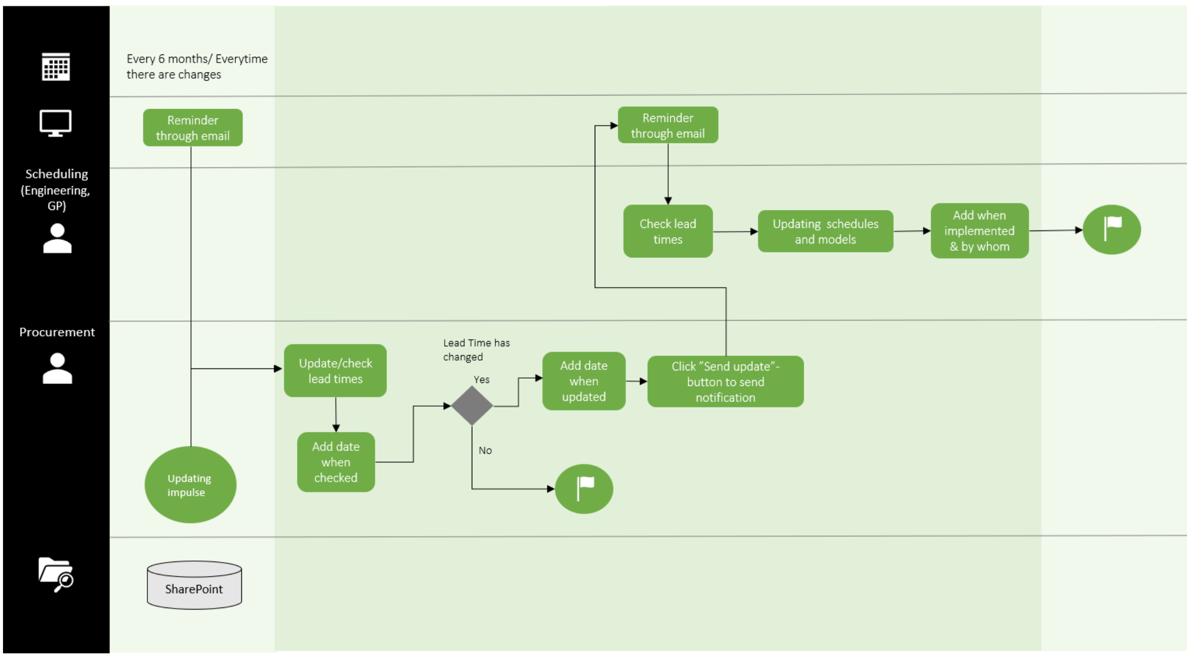

Figure 25 The new process of updating lead time information

In the updated process, the start impulse and updating frequency were defined. This way, due to a periodical updating frequency, all groups utilizing the file can be sure that the file does not have older information than the last six months. For the procurement department, what dates should be updated, and when is also clarified, and when to send a notification about an update for relevant groups. For sending the notification on an update, a button was created for the file, with instructions on its use. This way the people updating schedules could get immediate notification on when a new lead time is updated and so can transfer this to the schedule models as quickly as possible. For the schedulers likewise, the content that should be updated is marked. All in all, it can be seen that making the actual file accessible through SharePoint to all stakeholders that use it, is a major improvement, through being able to see real-time updates instead of having to rely on the copy that would be updated whenever.

What is still evident from the updated process, is that the ERP system is not integrated into the process. It was noted during the research, that the updates of lead times were not transferred to the ERP system. This could lead to risks if the new lead times are updated to the schedules and models and then released from engineering and LDP according to the schedule, but as they are transferred to the ERP system, the MRP considers them with the old item data and lead time. This could lead to the MRP guiding purchasing incorrectly and would mean that items could come to purchase either too early or too late depending on if the lead time has been shortened or lengthened. However, this is not the most critical matter currently, since many purchasers do not make purchases solely based on the information that is in the ERP system, but also based on their expertise, PN notifications, and impulses from other departments. This considered, it could be still argued as something that should be considered in the future if there is a motive to move into a system where the MRP would be able to guide purchasers, and purchasers would be able to trust the information the ERP system provides, and act according to it.

5 Discussions and Conclusions

In this section, insights and concluding remarks based on the research results are presented. First, the answers to the research questions are summarized, after which insights from the analysis on Project D are considered. Finally, the aspects relating to communication between different departments involved in the study are discussed along with some suggestions on possible ways of improvement. This paper ends with consideration of future research implications along with the limitations of this research.

5.1 Answers to the research questions

This thesis has investigated how is the scheduling process operated in a Finnish technology organization, and also considered on a general level how information on lead times is communicated between different departments within the organization. In order to examine this topic in detail, an analysis on the schedule of a previous project was performed. As the planning stages of a project are proved to be crucial on the overall delivery of a project, this study focused on the beginning stages of the scheduling process (Artto & Wickström 2005).

This thesis aimed to answer the main research question of "How could the risks in the project scheduling process be minimized with support from procurement?" The research presented, that a way to do this would be through providing timely, accurate, and easily accessible information on lead times and their changes to essential internal stakeholders who use it in their scheduling processes. In the context of the case organization this was carried out by updating the process concerning updating lead time information of critical items or items with long lead times to a shared Excel file, that the scheduling personnel use in their schedules and models.

Based on the result of the study, an updated process map was created (Figure 25), to depict the process of updating lead time data information to schedules and models. Compared to the previous process (Figure 10), the responsibilities and actions required by different departments were clarified, and a new convention regarding the updating frequency was established. There was also a new tool created through which it would be possible to notify schedule makers on updated lead times if those appeared outside of the normal updating convention. The new process (Figure 25) also included a feedback loop, through which it was possible for procurement to see when the new lead times had been updated to schedules. According to the thesis interviews, and general discussions with the employees, a depiction of the current general process of project engineering scheduling was also created (Figure 9). This answered the first thesis sub-question of “How is the current project scheduling process operated in the case company?”

The second sub-question of “How can project scheduling be enhanced in the case company through the means of procurement?” was investigated by examining the current processes, and the delays that occurred in Project D, as well as the general information sharing within the organization's departments. Timely, accurate, and early information was presented as most important and helpful when it came to sudden and quick changes, which means that through actively updating and communicating new lead times to the established Excel file and making sure the information they communicate to others is timely, procurement can help to enhance the scheduling process. As the procurement function communicates directly with suppliers, ensuring that suppliers communicate important information regarding possible schedule delays proactively, so that the procurement departments could communicate this information to other internal stakeholder groups as efficiently as possible is how procurement could aid not only departments involved in scheduling but also other functions.

Overall, it can be seen, that the scheduling process in the case organization operates effectively and well but has not in all cases responded well to sudden disruption deriving from the external environment. This was also a possible risk presented in the literature by Rane and Narvel (2021) who mentioned that the current project procurement management is not flexible enough to account for these quick changes and that there is a need for processes that are agile in nature to be able to respond to the changing environment. It was also mentioned by Laari et al. (2023) that a prerequisite for this was enough information visibility and data transparency between procurement and other supply chain processes. This factor was highlighted in the research results also between other departments besides procurement, in the own processes of different departments when it came to being able to do tasks according to the planned schedules. As component unavailability and uncertainty regarding the availability of needed resources are prevalent issues in the current volatile business environment, preparedness and ability to adapt are required from project schedules, and as this thesis proved, information needs to be effectively utilized to combat these challenges.

5.2 Insights from Project D

When considering Project D, and the factors interviewees brought up relating to the delays, it is evident that the global situation at the time played a significant role. It was noted that the components that experienced availability issues, were also such that made executing the following steps impossible. Even if the engineering and LDP processes were done according to the initially planned schedules in the cases included in the schedule analysis, the orders came late according to the engineering schedules. This would suggest that the lead times and the purchasing times were determined as too short in the planning stage. This in turn would imply that there was no knowledge that the lead times could be so long, and which components could be vulnerable to these sorts of risks.

It could also be concluded that when initial information on prolonged lead times was received, the initial estimates were not severe enough, the information had come too late, or had not been communicated effectively or quickly enough. Especially in many cases regarding the engineering process, according to the schedule analysis, the activities were so far executed, that changes were very difficult to implement successfully. It has to be noted of course, that in some cases without the corrective actions, the situation might have been worse, and even though according to the analysis, information might have been received too late, it might have been the earliest instance when the information was available. It is also possible that in the case of some critical components, there were no substitutes available, meaning there were very few ways to respond to lengthened lead time. However, these factors could bring up questions on the preparedness of the current processes to respond and handle sudden changes that have to do with factors outside of the organization.

Other causes of delays were dependent on the department and its processes, but even though the instances were different, what was common in many instances was that they related to information. Information was either not available, in the wrong format, or not received at the appropriate time. Not all instances were such where procurement had any involvement or could affect the activities, but it could be concluded that by making sure that in their part, procurement provides information on lead times, products, and suppliers effectively, it is possible to support other departments in uncertain circumstances.

Another notable factor from the scheduling analysis, was that a great part of the delays that were marked for the items according to the engineering schedules, were not marked as late deliveries in the ERP system. One factor behind this, is that the ERP system handles schedules at a much more detailed level than the engineering schedules, meaning the distinct requirement dates might be different between the ERP system and the main schedules. For example, if the supplier had to delay the assembly schedule, this information is updated to the ERP system but not necessarily always into the main schedules as was mentioned in previous sections on the scheduling process. Another instance has to do with the practice of updating new delivery dates, which is why sometimes the deliveries are not logged as late into the system.

It was also quite evident that the holiday season was a notable factor as a cause of delays in many processes, most notably the engineering and the LDP. This could raise a question regarding why the action points are placed during the holiday season and not before it, but the topic is not straightforward. When an action point is placed in the middle of a holiday season, a buffer is automatically added to the process times to take into consideration that the task might not be immediately completed. If an action point is placed before the holidays, this buffer is not automatically added. Of course, if action is performed before the holidays, it is done earlier and has a higher likeliness of being on schedule, but as was brought up in the interviews, the workload can be higher before the holiday season, and so the possibility that an action is not completed before the holidays can be more significant. Also, in this instance, if an action is not done, there is no planned buffer in place for the holiday season. This can lead to other subsequent actions being delayed from their planned schedules.

Altogether, a common factor found in the interviews was that interviewees connected the lack of issues in the current scheduling process to the fact that the product structures are well-modelled. Interviewees from engineering and procurement both mentioned when asked about the possible risks in the current scheduling process of Categories 2 and 4, that they saw the risks as low since the needed components of each product and structure were well recognized and that the components that have longer delivery times are known well. This was proved to be true in the case of Category 4, where a significant amount of the delays could be traced back to the model of the structure and to the fact that it had not been manufactured often and was not as well modelled.

5.3 Discussion on the scheduling process and information sharing

At the beginning of the thesis, the framework of RDT was presented as an explanatory concept behind the ways organizations operate in order to control the resources available to them, and how uncertainties caused by the resources guide processes. In the case company, the most prominent factor behind delays was noted to be the uncertainty concerning component lead times. According to De Meyer et al. (2002), this type of uncertainty could be defined as foreseen uncertainty as changes in lead times are possible, however, due to the severity of the changes, it could also be seen as unforeseen uncertainty, since adequate measures were not already established to answer cases this severe. What came up from the interviews, was that it usually is people's own responsibility to inform and communicate forward the information when drastic changes occur. It was also brought up that in some cases this information was communicated too late.

What can be concluded, is that many instances of schedule delays could be seen as being caused by inefficiencies in information processing. As mentioned previously in the theory, information processing was a notable factor when it came to the effectiveness of internal processes especially in volatile environments (Bode et al. 2011; Felin et al. 2016). It was also stated for instance by Sharma et al. (2023) and Hackett Group (2015), that procurement has useful information that can aid other departments and processes, but what came up in the research, is that it loses its power and positive effects, if it is communicated too late, or otherwise difficult for other departments to access. In the context of the case organization's process of updating long lead times of items, this was showcased as not up-to-date information in the Excel-file. There can be seen other barriers to efficient communication of this lead time information such as unclear processes, which in this context meant uncertainty in the procurement department on how the lead time information is utilized in reality, and what would be the most useful way to use the Excel file. Although the majority of this thesis focused on lengthened lead times, and how information is shared in these cases, another consideration is the communication associated with shortened lead times, which can sometimes be left with less focus due to the fact that a longer lead time is more likely to cause issues. It should however not be completely left without attention, since too long of a lead time without a real need, could lead to inefficiency, and overall wasting the scarce resources that would be needed elsewhere.

When it comes to managing the uncertainty around longer lead times and how information could be communicated more efficiently, the process depicted in figure 25, can be seen as a one way in which this could be addressed, particularly if quick short-term solutions are needed, since a notable fact that came up from the interviews, was the importance of how quickly and effectively information on lead time changes is received. Another notable topic that came up from the interviews were the comments made by both of the engineering personnel, on instances when the information on drastic changes on item's lead time was communicated too late. One interviewee even commented that in their viewpoint it seems like purchase order monitoring is not conducted in the case organization at all. Even though from the viewpoint of procurement this may sound somewhat harsh, it tells how the situation appears to the person interviewed. Even though suppliers and purchase order lines are monitored by procurement personnel, due to the number of purchases done daily, it is not possible to follow intensely every order, or continuously confirm from the supplier if they are staying on schedule. This is why, if the supplier does not proactively communicate, or the procurement personnel themselves are not constantly asking after orders, it is possible that the lengthened lead time might come up only when it is close to the planned delivery date of the order. Of course, it can be that sometimes suppliers do not have that information available to themselves either due to their own material suppliers for example. In order for the procurement personnel to communicate lead time information to other departments, they should have access to timely and accurate information as early as possible.

One way to improve procurement personnel access to lead time information could be by making sure information on the lead time is available as soon as possible. Besides asking suppliers directly if they are staying on schedule, procurement personnel get information from their suppliers when the supplier confirms the order and the requested delivery date. If the supplier does not confirm this delivery date requested by the person placing the order, the procurement personnel does not have information on whether the requested delivery data is possible or not. According to the case organization, suppliers should do this within 48 hours of receiving an order, but at the moment this is not true with every supplier. By communicating that early confirmation from suppliers is expected, information on if the requested schedule is possible or not could be gained as early as possible and communicated forward to other functions. Important factor is also that the delivery date the supplier confirms is as accurate as possible, and not confirmed just because it is required by the case organization. Early confirmation of a delivery date is not useful information if it is then later changed multiple times. In the most ideal case suppliers would be proactive and themselves communicate as early as possible, if they cannot make the original receipt date they have confirmed, even without the procurement personnel needing to ask first. Since procurement personnel cannot ask after every order they have place, the objective should be being able to trust their suppliers to communicate this information, this way the information would not be received only when the purchaser asks why the order has not arrived yet, which was the reality brought up in interviews.

Recognizing, with which suppliers the communication on lead times would need to be developed, could be done by analysis and monitoring of supplier on time-delivery percentage, and the percentage of how quickly, and accurately the suppliers confirm the received orders, and how often with a certain supplier the delivery dates are changed from the original requested date. This would give information on which suppliers are more unreliable in this case, and with which suppliers this topic could be addressed and improved. This would also give information to the purchasers, if they themselves could have purchased the item too late if suppliers continuously confirm other dates than the one requested.

When suppliers confirm a delivery date, the information is transported back to the company's ERP system, which also means that the accurate information is available to many other departments. Many other departments for instance the LDP base some of their operations based on the information that is on the ERP system, which is why ensuring that this information on orders is up to date should be prioritized. The role of procurement in ensuring that the information if the ERP system is current and accurate especially when it comes to the date the order is expected to be delivered, is vital, as information on lead times is the type of information other departments need and might have difficulty accessing. Overall, departments within the organization each have different expertise and can have access to a certain type of information that another department does not have direct access to. This itself could sometimes cause risks if there is information that is only in certain areas of the organization and not on an accessible level.

5.4 Future research

As unexpected events in the business environment played a significant role in causing difficulties for organizations to adhere to the planned schedules, in the future, investigating what are, or should be the established ways of working in the case of dramatic disruptions, especially relating to availability challenges or drastic changes in the lead times could be investigated. Since it was mentioned previously that literature has recognized the inability to forecast item lead times as a cause for issues in project schedules, and the same was also noted in the case company, finding ways in which item lead times could be forecasted more effectively, and changes prepared for is also a notable future research area.

As communicating information on lead times and especially on their changes came up as an important theme in this research, clarifying to the needed stakeholders what this communication should be like in the case of a disrupting event, and if there should be an established process, could be for instance inspected from the perspective of supplier relationship management. From this perspective, it could be investigated how suppliers could be encouraged into more open communication when it comes to communicating lead time information and building trust that the information that is communicated is as accurate as possible.

Rane and Narvel (2021, 1149) mentioned the project procurement processes as being very “human-intensive” and relying on manual processes, which could also be noted at some level regarding this research, and the current scheduling process, at least in the sense that it currently relies more on either the personal skills or manual efforts by employees, rather than being an automated system. As Rane and Narvel (2021, 1149) recognized this as an issue and a barrier to agility, in the future, research could be made to investigate how this process could be automated, and how this different information could be integrated straight into the ERP system, or in a manner where people needing different information can access it directly without the current complexities. As mentioned, it is often people's own responsibility to inform and manage these change situations, which is why it would be interesting to examine how within an organization disruption caused by the business environment are managed.

5.5 Limitations

This thesis has some limitations regarding its reliability and validity and the possibility to generalize the results. Through evaluating the reliability and validity of the research it is possible to draw conclusions on the overall quality of the study (Hayashi, Abib & Hoppen 2019). The possibility to generalize the results of the study remains very limited beyond the organizational context in which the research was conducted. Confining the scope of the study only into the two product categories (Category 2 and 4) also limited the extent to which the results can be generalized within the organization. Also, within the chosen categories, PNs had to be left out of the schedule analysis, due to issues with data traceability in the systems, and time limitations of conducting the research. The validity of schedule analysis on Category 2 can be seen as a bit better since a greater amount of the Category's PN could be included in the analysis. In order to improve the validity regarding Category 4, as many PNs were included as possible, but even then, the causes of schedule delays are truly relevant only for the mentioned two categories, although it could be seen that especially the external factors mentioned in the fishbone diagram effected also other product categories similarly. Likewise, the more similar the scheduling process, product or components to those investigated in this study, the more relevant the results could be seen as.

There also exist some limitations to the reliability of the quantitative data and the accuracy of the data in describing reality. It should be taken into consideration, that the data used for tracking project purchase information came from the company ERP system, and the time when specific data about a purchase is logged into the system might not tell the reality of where the materials have been. For instance, when it comes to the order date, an order might be agreed upon with the supplier through email and put into production, but the official order is sent and logged into the system at a much later date. This can mean that some of the order dates registered into the system do not equally present the same information. The case is similar to the order receipt dates, as sometimes there might be general lag in the system, or other external factors preventing the proper registration of the receipt into the system, even though the order already has arrived. Due to this, in some cases, the number of days an order has been late according to the system is not accurate. The validity of the results of the one-way ANOVA test are weakened by the small sample size, which negatively effects how well the test depicts the reality, and how accurately the test depicts the differences between the two categories.

The limitations and possible fault margin in the quantitative data were one of the motivations for interviews, through which it was possible to gain knowledge on the actual process and clarify the possible uncertainties relating to the schedule analysis and quantitative data which can see a improving the validity of the results.

Evaluating the validity of qualitative research has been mentioned to be more challenging compared to the evaluation of quantitative research, due to the more various research methods and the lack of universal assessment criteria. (Hayashi et al. 2019) The main qualitative research method utilized in this thesis were interviews, and the results can also be seen as limited, due to the time constraints and schedule of the thesis, which meant that the interviews could be conducted with only eight participants and include only a limited number of people from each department. This weakens the interview results in the sense that they cannot be directly generalized to the whole department.

Validity and reliability of the interviews is also hindered due to some results being reliant on personal observations and conclusions based on previous experience and the interviewing situation, meaning that if a different person were conducting the interviews the results and observations could be different. The same applies for the people who were interviewed since their insights and responses were based on their own opinions and perception. However, it is mentioned that the usage of different supporting materials such as quantitative analysis enhances the validity of the conclusions, which is why both were used (Creswell 2009, 190). The validity and the possibility of system errors were also considered, and one of the motives for using a mixed method approach and going through the cases in the schedule analysis with the interviewees was to see, if the data depicted in the analysis, would correspond to the actual occurred instances. This improves the validity of the results from schedule analysis, as they have been confirmed through interviews. The validity of the interviews is also enhanced due to choosing people for the interviews who were directly involved in the cases that were presented, and so could provide more reliable information. For instance, the interviewees from the procurement department were shown cases were greatest delays in the whole process seemed to be caused by their own purchases.

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Appendix 1. Translated interview form.

Interview form Vilja Aalto

The interview consists of two parts, out of which the first is freer in form and includes free discussion relating to the schedules of Project D (actual vs. engineering schedule), and generally to the process of updating item lead times and utilization of information relating to project schedules.

The second part of the interview is more structured and includes questions relating to lead times, the schedule planning process, and sharing and maintaining information between internal stakeholders of the organization (Engineering, Global Planning, LDP, and Procurement). In this section, there are references to an Excel table, which refers to the data file on critical and long lead time items maintained by procurement.

Part 1

Scheduling process

- Briefly describe your own tasks
  - What challenges do you recognize in your tasks relating to the scheduling process?
  - Do you recognize situations where procurement could better support the scheduling process?

Project-related questions (Project D)

- What was your own process like regarding Project D, especially relating to the presented examples (e.g. Was it possible to start procurement activities on time? Were there any challenges in engineering? Dates registered in the system vs. the actual receipt date, challenges of the suppliers, etc.)

Part 2

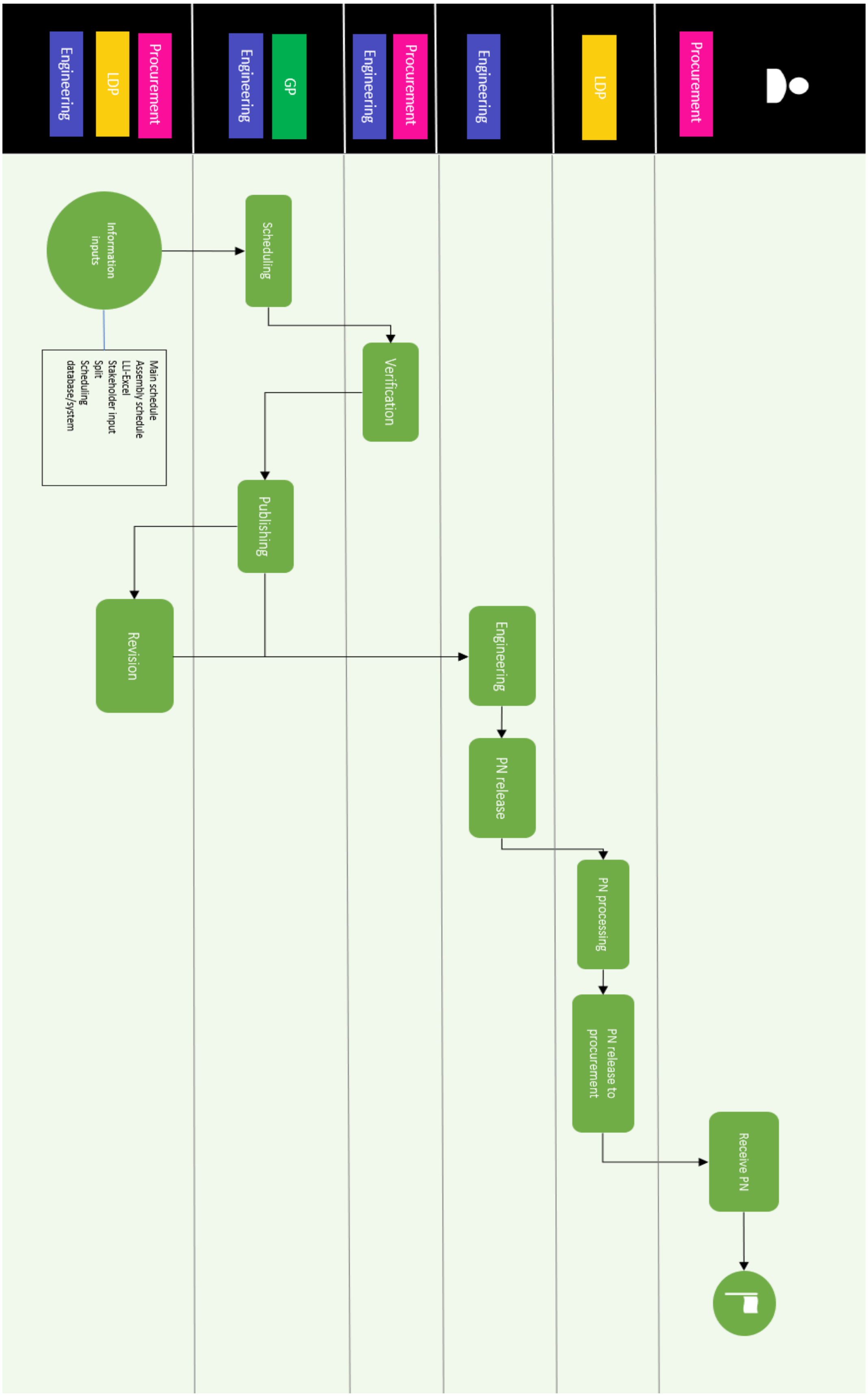
Sharing and utilization of intra-organizational information

- How is information shared between different stakeholders within the organization? What is this process like relating to changes in lead times/procurement schedules?
  - How effective do you see the current information exchange?
  - Do you feel like the necessary information on schedules and requirement dates is easily available?
  - Should there be more information exchange between stakeholders compared to the current situation?

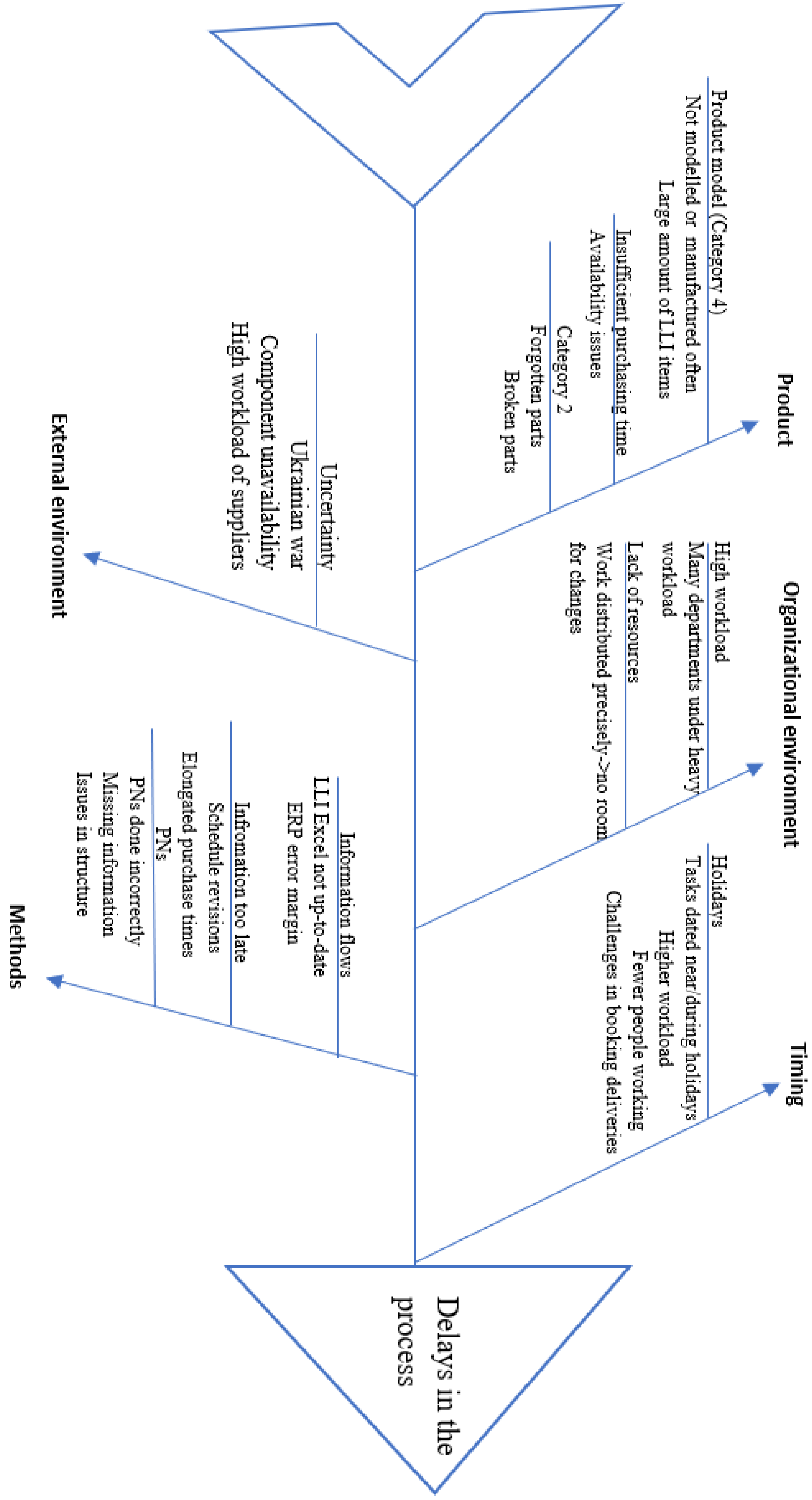
Communication of information relating to lead times

- How do you see the current practice of updating information on item lead times?
  - How often do you think the lead time information should be updated/checked?
- In the current Excel file, are there some components that are challenging to identify?
- Do you think that the file should be flexible vs. invariable? (Could items be added/removed from the Excel as lead times shorten/grow)
- Do you feel that topical information on supplier lead times is available?
- How do you see the current process of finding out item lead times?
- How trustworthy do you see the current lead times and how prone are they to changes?

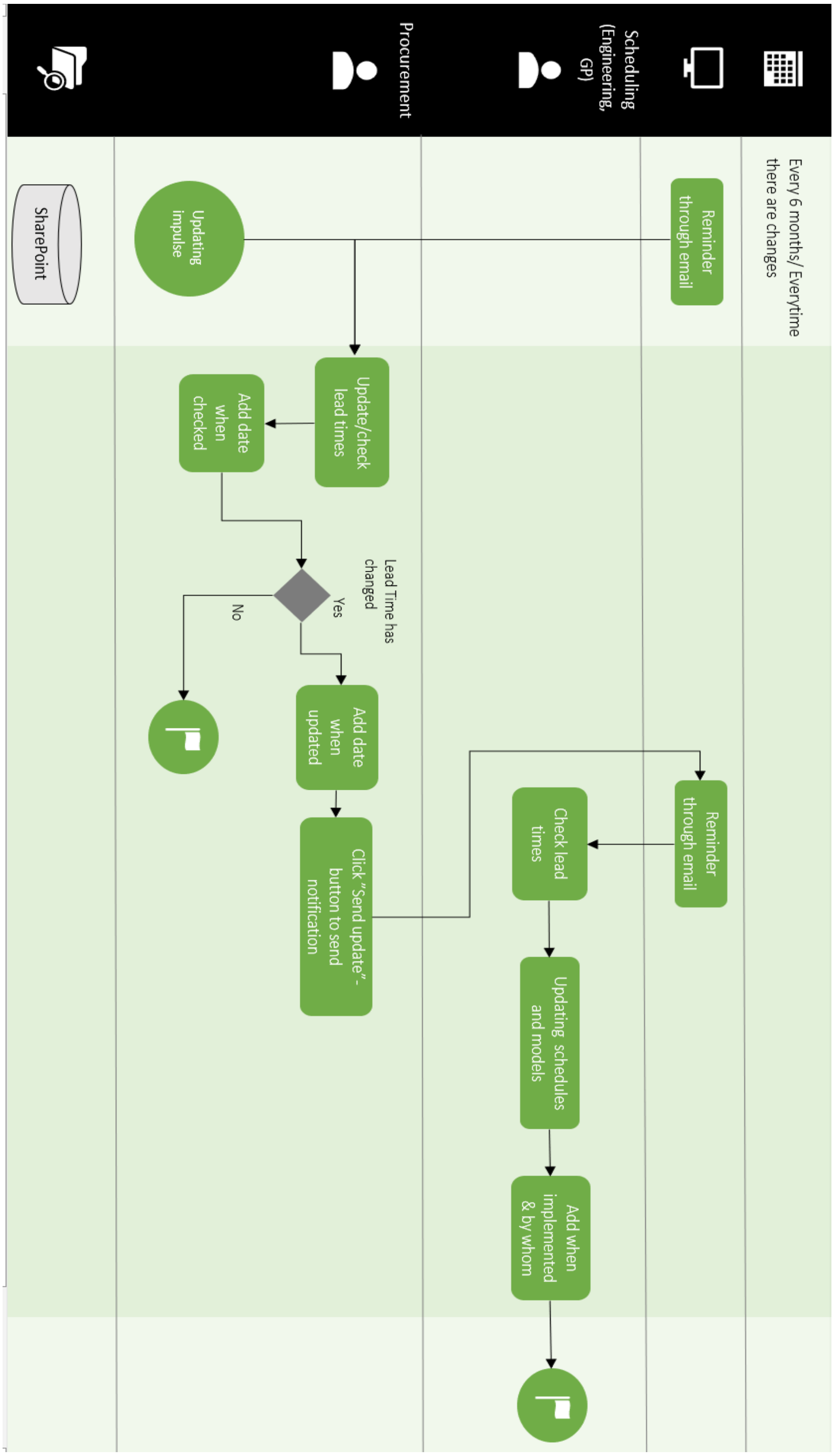
Appendix 2 Full picture of the engineering scheduling process



Appendix 3 Full picture of the fishbone diagram



Appendix 4 Full picture of the new process



Appendix 5 One-way ANOVA

Anova: Single Factor Engineering delays

SUMMARY

Groups	Count	Sum	Average	Variance
Category 1	13	35	2,692308	85,23077
Category 2	26	139	5,346154	48,71538

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	61,03846	1	61,03846	1,00793	0,32192	4,105456
Within Groups	2240,654	37	60,55821			
Total	2301,692	38				

Anova: Single Factor LDP process times

SUMMARY

Groups	Count	Sum	Average	Variance
Category 1	13	123	9,461538	186,1026
Category 2	26	161	6,192308	129,9215

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	92,62821	1	92,62821	0,625265	0,434137	4,105456
Within Groups	5481,269	37	148,1424			
Total	5573,897	38				

Anova: Single Factor Receipt delays

SUMMARY

Groups	Count	Sum	Average	Variance
Category 1	13	88	6,769231	39,19231
Category 2	26	235	9,038462	63,23846

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	44,62820513	1	44,62821	0,804986	0,375408	4,105456
Within Groups	2051,269231	37	55,43971			
Total	2095,897436	38				