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Transition of the production system at a manufacturer

Master's thesis in the Master's Programme Supply Chain Management

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SUMMARY

In today's context, in order to stay competitive in the manufacturing market, companies need to both provide high customisable products and short delivery times. This thesis investigates the transition of the production system at Company Alpha, going from a project-based, make-to-order (MTO) approach toward a hybrid production model, incorporating make-to-stock (MTS) strategies. This is what the company refers to as product-based production planning. The study aims to map the current production and planning setup, identify areas of problem through a low hanging fruit matrix and propose suitable improvements to align with a hybrid production structure. Further, it aims to identify possible effects the transition can achieve. A mixed-method approach was used, including a pre-study, literature review, case study, interviews, and observations, to gain an in-depth understanding of the company's operations and identify key processes.

The findings revealed significant misalignments between planning and execution, caused by capacity constraints, inadequate cross-functional communication, and reliance on infinite-resource assumptions. The results are continuous rescheduling, requiring valuable time from all roles involved in planning and production, causing an unstable schedule and flow. To address these issues, the study proposes a series of changes connected to the transition including product segmentation, optimal decoupling point determination, adjusted lot sizes, and improved capacity allocation. Also changes outside the transition such as enhanced cross-functional collaboration, usage of safety stock, and improved measurements are suggested. The analysis shows that transitioning to a hybrid planning model can reduce lead times, increase delivery precision, improve capacity utilisation, and enhance overall efficiency and customer satisfaction. This thesis contributes practical insights into how manufacturing companies can successfully manage the shift toward hybrid production systems. It highlights the importance of aligning planning and production and balancing efficiency with flexibility to meet today's dynamic market demands.

Keywords: Material resource planning (MRP), lot size, capacity planning, standardisation, make-to-stock, and hybrid production structure, make-to-order, decoupling point, cross-functionality, manufacturing industry

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List of Abbreviations

MTO - Make-to-Stock
CO - Customer order
SO - Shop order
PO - Purchasing order
PR - Purchase requisition
MRP - Material requirements planning
BOM - Bill of material
MPS - Master production scheduling
SS - Safety stock
FOQ - Fixed order quantity
EOQ - Economic order quantity
L4L - Lot-for-lot
POS - Period of supply
POQ - Periodic order quantity
LUC - Least unit cost
LTC - Least total cost
PPB - Part-period balancing
CRP - capacity requirements planning
S&OP - Sales and Operations Planning
NCR - Non Conformance Reports
SFG - Semi-finished goods

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1. Introduction

The first chapter will provide an overview of the study, including background of the topic, purpose, demarcation, research questions that are to be investigated and answered, and a definition of project- and product-based planning.

1.1 Background

The manufacturing industry has become more competitive over the past few years in terms of service level and efficiency, pressuring companies to adapt quickly to the new environments to stay competitive (El Maraghy & Wiendahl, 2009). Adding to the complexity is that the industry is changing within all areas of the triple bottom line simultaneously (Khandelwal et al., 2025). Technological advancements, globalisation, and increased customer power are some factors that contribute to and showcase the importance of being agile and working proactively (Rocha et al., 2015). This agile way of working applies to all areas within the company, being agile can be translated to a flexible way of working in production, and its planning processes. Product planning ensures the right material at the right time and right amount to produce the demanded output created from the specific schedule. Since the mentioned functions are interrelated, any issues in securing the required materials may lead to production constraints (Temponi & Vandaele, 2018). Showcasing the great importance of adapting the methods used within product planning to the environmental challenges in order to stay competitive and maintain satisfied customers.

Planning work has become increasingly difficult especially due to the added complexity of customer specifications on the demanded goods. This entails that companies are required to manufacture lower volumes, aggravating economies of scale on already technologically advanced and expensive products (Mustafa & Cheng, 2016). These complex products often entail many smaller modules which can vary greatly in manufacturing time adding another layer of complexity to the planning. Furthermore, difficulties connected to a highly inconsistent order flow have shown to become an increasing problem (Adediran & Al-Bazi, 2022). This results in producing smaller batches due to high costs of stock up and uncertainties leading towards working to a high degree with a Make-to-Order (MTO) environment.

However, an MTO approach may not always be the most suitable, as this strategy does not plan for future spikes or decreases in demand, nor an increase in customer specifications (Ghasemi et al., 2024). Not accounting for these scenarios often results in long lead times, making companies less adaptive and slower to respond to customer orders. This, in turn, can result in reduced service levels and lower customer satisfaction (Rajagopalan, 2002). Therefore, conducting research on the potential benefits of transitioning from a MTO towards a Make-to-Stock (MTS) planning approach to a higher degree is highly relevant. In more detail, transitions within applicable modules and related areas of the production in order to solve consolidation issues. Thus, changing the planning approach of production may lead to improved efficiency, faster response times, and thus, enhanced service levels (Köber & Heinecke, 2012).

In this study, company alpha is facing a decision of the change as they want to gain a deeper understanding of today's structure and flow both within production and planning. Gaining more insight into how those functions interact and collaborate in order to improve the current way of production planning. This requires identifying and mapping today's processes ranging from the planning of the material until the final assembly of the product, using academic insights in the area to adapt and generate new ways of addressing the problem, and suggests improvements. Additionally, with roots in the theoretical framework, present achievable effects of this transition.

Although this transition is difficult and may not be applicable in all areas, several different studies conducted within the area of production planning exhibit potential changes that could be made. Jonsson & Mattsson (2009) state that by capacity requirements planning in the right environmental context can improve the order flow and secure a levelled-production. Furthermore, by conducting a segmentation of the products, introducing a decoupling point, and determining the correct lot size Perona et al., (2009) presents that it is possible to increase the delivery precision and decrease costs with 36%. Additional study on segmentation conducted by Rafiei & Rabbani (2014) has shown to reduce the average lead, increase delivery precision and reduce the backorder log. By also conducting a capacity allocation prioritisation it is according to Rafiei & Rabbani (2011) possible to achieve a higher degree of on-time deliveries, reduced backlog, and reduced overtime work.

1.2 Purpose

The purpose of this study is to explore the transition from MTO to MTS planning for a specific product segment, which is defined by the case company as projects-based to product-based planning. It first aims to map the current production system and planning processes with the intention to identify their relation and coordination. It also intends to suggest the changes that can be made to make a transition to implement product-based planning to a higher degree into the planning system. Lastly, it aims to analyse the potential effects of the transition on the production and planning areas.

1.3 Demarcation/Scope

This project focuses on a specific product-family and its internal material flow, the planning phase of the product until it is assembled at the production facility. The primary focus is on the planning methods used for the specified product. The production layout in the facility is fixed and non-adjustable and potential changes regarding this will therefore not be addressed. However, the related production strategies e.g. material handling, standardisation, make-to-stock, make-to-order, lot sizes, and inventory management will still be analysed in order to map the situation and propose recommendations within planning. The results will not be measured against any specific KPIs, but rather on a broad term in order to not miss out on any interesting findings for the organisation.

1.4 Research Questions

The research questions have been formulated to address company Alpha's transition. They are designed to provide a structured approach to analyse the current state and to deliver insights for the company. These insights will support the decision-making and implementation of the potential results of the study within the organisation. First to assess the current state before the transition, RQ1 was formulated:

> *RQ1: How is the production and planning set up and how do they coordinate?*

This is done to assess the current production system and material flow by gathering and analysing data from reports, documents, and other relevant sources, as well as conducting interviews and observations to gain further insights. Furthermore, it will examine and map the planning processes in relation to production and examine company Alpha’s current operational systems, comparing them to theoretical models, and referring relevant literature to identify areas for improvement.

> *RQ2: What changes within planning can be made to transform from project-based planning to product-based planning?*

In RQ2, theoretical models and previous findings on transitions conducted in similar environments will be used and compared against the current state to identify and propose changes for transition from project-based to product-based planning within applicable areas of the organisation.

> *RQ3: What potential impacts will these changes imply on production and planning?*

RQ3 was formulated to assess, based on theoretical strategies and previous findings, which effects the transition of the production will have on the organisation. Being on the production, planning, and identified problem areas.

2. Theoretical Frame of Reference

The theoretical frame of reference will provide a foundation for the study, presenting key strategies related to planning and production, including aspects of order planning and manufacturing strategies. Additionally, previous findings from research conducted on other companies in similar environments will be addressed.

2.1. Material Requirement Planning

Material requirement planning (MRP) is a system used to facilitate planning and ensure enough available materials to cover the demand (Grubbström & Thuy Huynh, 2006). Its objective is to determine both gross and net requirements for all necessary items over a couple of predetermined discrete time periods (Ptak & Smith, 2011). This is done in order to maintain the correct inventory levels by generating order actions. Those actions pertain both to production as a shop order and to procurement expressed as a purchase order (PO). It consists of the required item quantity, item identity, date of order release, and what date the materials are required. Both the input and output can be seen in Figure 1 below and will be addressed in more detail below.

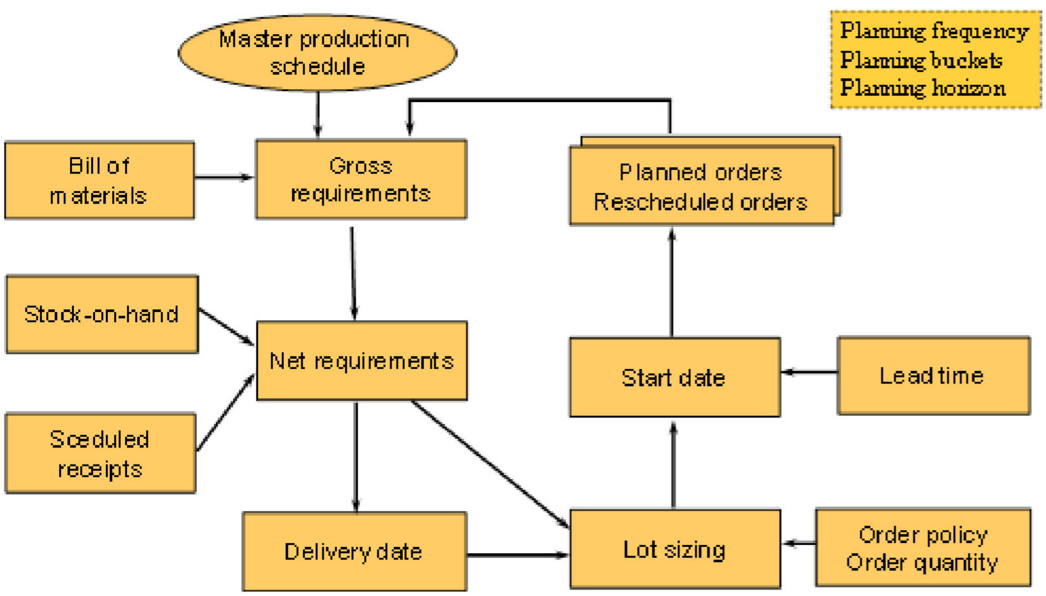

Figure 1. MRP inputs and calculation process (Jonsson & Mattsson, 2009) Reprinted with permission.

Before a MRP system is implemented there are a couple of important functions and planning factors that need to be determined and understood, acting as the system's input. The functions are bills of materials (BOM), master production scheduling (MPS), and Inventory status. Those along with the planning factors enable the MRP system to generate the output in terms of production plan and PO's see Figure 1. The planning factors are the length of both time periods and the planning horizon, time fences, planning frequency, order types, and handling of rescheduling (Jonsson & Mattsson, 2009). Important when considering the planning factors is that when deciding the planning horizon, it must at least stretch as far as the longest accumulated time of procuring and producing all items involved in the end product (Jonsson & Mattsson, 2009). Deciding an appropriate planning frequency as it refers to how often existing orders are rescheduled or new orders are planned. The closer to the present we stand the more accurate the orders while those further away in time are more heavily based on forecasts.

The first function is the bill of material, which is an engineering document providing insight into all required items to complete the end product (Orlicky et al., 2003). It creates a system showcasing the dependent demands, meaning no forecasted values on lower levels are required since it is enough to forecast the end product and trace the demand upwards (Olhager 2013). Since MRP systems are product-oriented it is dependent on understanding the structure of all required times such as raw materials, semi-finished manufactured items, and purchased items (Jonsson & Mattsson, 2009). The second function is the MPS which provides broad high-level information to the MRP system. The MPS creates a plan specifying what products need to be produced on an end-product level. It also shows what quantities are required and when the products need to be manufactured. It translates customer orders and forecasts into a production schedule using a time horizon of half a year to a whole year and functions as the starting point for the MRP system (Jonsson & Mattsson, 2009).

The third function is inventory status, which serves as the basis for decisions regarding whether purchasing orders need to be created or not. It is used in the calculation of net requirements which provides the system with the outputs in terms of purchase orders and a production plan. However, to generate the production plan, the required POs are created from different order actions. Order actions toward purchasing exist in two forms. Firstly as a requisition order, demanding the items to be bought based on control of the current inventory levels which is reviewed by purchasing (Ptak & Smith, 2011). Secondly as a subsequent order which acts as the formal purchase order placed directly at the vendor. It is also possible to revise an order, however, it is limited to what is possible. Those limitations are, increasing or decreasing the quantity, cancellation of order, adjustment of order due date, and suspension.

To determine what output should be generated, whether a purchasing order (PO) or shop order (SO) of any sort, the MRP system bases its calculation on the net requirements which are compared to the inventory status. This is calculated by initially using the gross requirements subtracting the on hand stock and pending order quantity, leaving the net requirements (Ptak & Smith, 2011). If this equals to a negative number after also considering the safety stock (SS) a PO needs to be generated. However, if a positive number appears enough materials are already available and there is no need for a PO to be generated. The fundamental principle behind this method is to avoid generating orders before a net requirement is identified (Jonsson & Mattsson, 2009). This is to avoid unnecessary stock-up costs.

The net requirements are always checked against a predetermined time period ensuring materials for that time frame (Ptak & Smith, 2011). The size of the PO depends on the company's strategy where several lot-sizing methods are available to choose from. Furthermore, the date for planned-order releases is stored and decided by the MRP system to act as a base for future order actions. Further functions offered by the MRP system are rescheduling of orders for both POs but also SOs. If net requirements are not possible to fulfill it signals the user and suggests a possible reschedule whether backward, or forward to provide coverage of net requirements

2.1.1 Time Fences

A problem regarding production scheduling is connected to the dynamic nature of time (DeYong & Cattani, 2016). Yesterday's schedule has become obsolete today, and requires a modification with today's information to stay relevant. Changes made to the production schedule can cause problems, especially if they occur close to the production start date. Those problems can be, lack of available capacity, material shortages, starvation, or to high stock levels adding unnecessary cost. A solution to mitigate the negative effects is to introduce time fences, described as a period where scheduling modifications are restricted. Changes outside the time fences are allowed without any constraints, but within they are restricted differently depending on what type of time fence.

There are often two time fences used in planning creating three differently strict time zones that can be used to minimise the cost of rescheduling (Jonsson & Mattsson, 2009). The first fence is the release time fence found closest to today's date. The length of this time fence equals an order throughput time in the workshop. Within the release time fence orders are already released prohibiting rescheduling. However, if changes for some reason are allowed it could result in increased production costs and decreased delivery service and production efficiency. The second fence is the planning time fence. It considers both the throughput time in the workshop and the time required from the order being placed until delivered. Since orders are already placed within this time frame, conducting changes here might be costly and disrupt the capacity planning in the workshops. However, the consequences are more moderate allowing for smaller changes to occur.

Between those two time fences and today's date, the earlier mentioned zones appear. The most strict zone is called the frozen zone, here the orders are set providing clear instructions to production and procurement.. It appears closest in time to today's date, see Figure 2. Within this zone it is not permitted to conduct any changes in the next planning cycle since the release time fence is passed, neither regarding timing nor quantity (Robinson et al., 2008). However, the best length of the frozen interval is determined based on a trade-off between visibility towards the vendor and production flexibility. The second zone is the half-frozen zone, which stretches between the release time fence and the planning time fence and allows some changes to occur. It retains the timing as frozen but allows for the quantities to vary (Robinson et al., 2008). The third zone is the floating zone, which extends beyond the planning time fence. This zone offers the highest degree of flexibility as orders have not yet been finalised, allowing modifications in both the quantity and time without high costs.

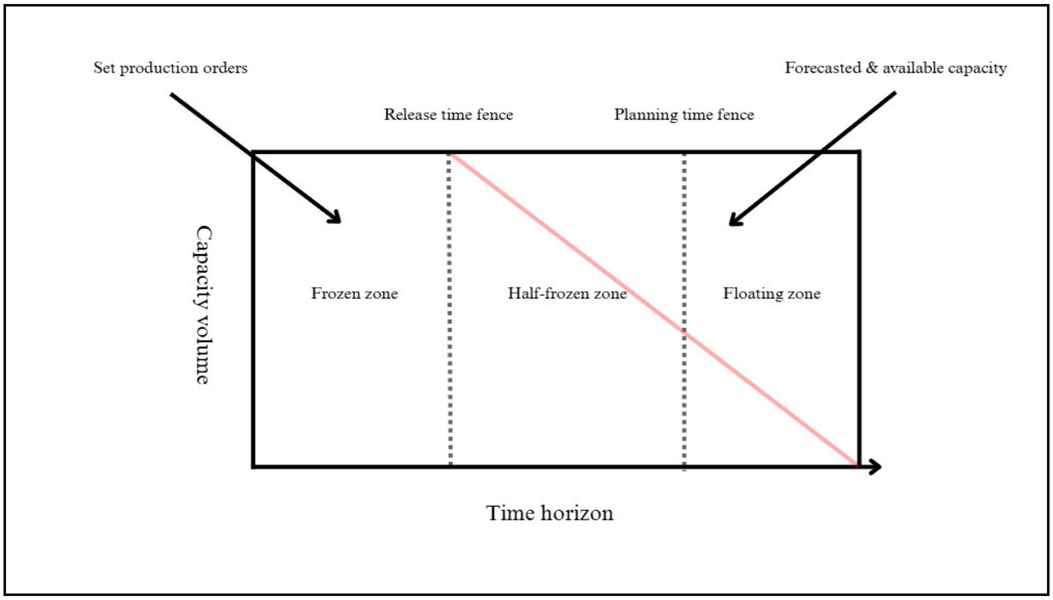

Figure 2: Visualising the time fence concept and presenting the two most common fences along with the three zones which appear. It also showcases where in time the orders are set production orders and where they are based on forecast, meaning they can be changed.

2.2 Lot-sizing Methods

According to Ptak & Smith (2011), lot sizing strategies have become increasingly important in inventory management since materials occur at distinct, separate time intervals, requiring updated demands. Two different costs are important to consider when calculating the lot size, these costs are ordering costs and inventory costs. Ordering costs are the costs included in the procurement but also the preparation of the production which are all the administrative costs, the waste associated with changing production layout, and managing the work-in-progress goods. Inventory costs are the costs related to carrying the goods due to storage and insurance costs, bound capital, and obsolescence. There are several lot sizing methods available, but the ones most frequently used are visible in Figure 3 below.

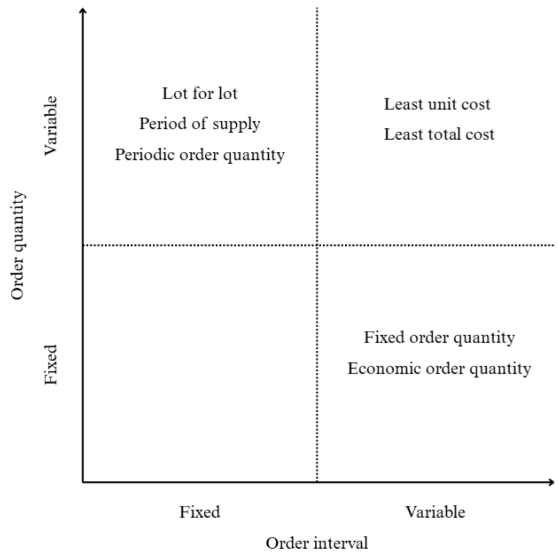

Figure 3: Presenting lot sizing methods based on time and quantity

In the lower right of the matrix, there are strategies that have a fixed quantity and variable ordering interval, these strategies are fixed order quantity (FOQ) and economic order quantity (EOQ), see Figure 3. According to Baraka & Munyaka (2022), FOQ is used when there is a consistent, predetermined quantity of a material/module ordered each time the inventory level reaches a certain reorder point. This makes the method specifically useful when there is a stable demand but also predictable lead times. The drawbacks are however that it is very limited as it does not adapt to fluctuations in demand well which often results in either overstocking or stockouts. Another similar approach is EOQ and it is most effective when there is a stable demand, consistent lead times, and fixed inventory costs. It aims to determine the most economical order amount, and requires the set-up cost, holding cost and demand. The volume calculated by EOQ must also always be possible to order, nor does it consider quantity discounts (Alnahhal et al., 2024).

The upper left of Figure 3 presents strategies that aim for a fixed ordering interval and variable order quantity. According to Jonsson & Mattsson (2009), lot for lot (L4L) is one of the simplest approaches to lot sizing as it orders the exact amount that is required for each period. Because of this, frequent ordering may lead to increased costs, additionally, this strategy also needs to keep in mind supplier constraints on minimum order quantities (Florim et al., 2019). This strategy does however minimise inventory carrying costs, therefore, it is commonly used on high-cost material and modules (Jonsson & Mattsson, 2009). The period of supply (POS) strategy is trying to minimise the costs using a broader time-period where intervals may vary. Therefore, this strategy shines where there is a stable demand as it is immobile to higher fluctuations, it also amplifies the use of bulk purchasing reductions. The drawbacks are however high holding costs due to the large orders (Ptak & Smith, 2011). Periodic order quantity (POQ) is a method which is converse with EOQ, meaning that the quantity ordered is irregular, but it is ordered at fixed intervals, therefore, the ordered batch must fulfil all requirements until the next batch has arrived. Here, minimisation of ordering costs are not as important but as the quantities are adjusted, potential reduction of inventory costs are possible. Furthermore, the strategy can also be easier to coordinate with other departments such as planning because of the fixed delivery schedules (Florim et al., 2019).

Four methods are also available if both varying interval and quantity is preferred. These approaches assume that inventory is depleted at the start of each period, which skips the carrying costs for that period. Therefore, these approaches aim to minimise setup and inventory costs similar to EOQ, but do this on assumption instead of average inventory. Least unit cost (LUC) acts as a trial-and-error strategy, whether the lot size should cover only the first period or further subsequent periods. This makes LUC's primary aim to reduce costs with a secondary mission to balance inventory levels (Ptak & Smith, 2011). Least total cost (LTC) is similar in terms of objectives, it calculates the sum of inventory carrying costs and setup costs and tries to get the costs as equivalent as it can get. This method will minimise the total costs, but does struggle in dynamic and uncertain environments as it does not adapt well since the focus is in line with EOQ (Noblesse et al., 2014).

2.3 Safety Stock

Synchronising demand and supply is generally difficult as uncertainties regarding both the demand side and supply side aggravate planning complexity. To hedge against those uncertainties, buffering mechanisms such as safety stock (SS) and safety lead times are applicable. The demand uncertainties mainly concern what quantity customers will demand, while the largest supply uncertainty refers to delivery precision. Moreover, the supply side also encounters uncertainties regarding errors within the stock levels, whether suppliers will be able to deliver, and the quality of delivered material and items. There is always a certain percentage of the supplied materials that do not fulfill the agreed quality and need to be scrapped displaying the importance of a SS (Jonsson & Mattsson, 2009).

Uncertainty hedging in material planning is possible through two principles, quantitative hedging and time hedging. Quantitative hedging refers to stocking up on more products than demanded while time hedging refers to receiving a delivery earlier than required, meaning extra time is added. Both ways lead to an expanded stock level and are referred to as a SS strategy. A common rule of thumb is that quantity hedging is applied in quantity uncertainties while time hedging is applicable for time uncertainties (Jonsson & Mattsson, 2009). This aligns with what is discussed by van Kampen et al., (2010) where they argue that safety lead time is most applicable when facing supply uncertainties since the planners receive more flexibility. Safety stock on the other hand, is more useful when facing demand uncertainties due to increased system responsiveness.

Balancing the total cost of carrying inventory and facing a shortage can determine the size of the SS from an economical point of view (van Kampen et al., 2010). A large SS implies a high inventory cost while a small one increases the risk of shortages and its connected costs which are lost revenue, delayed delivery fees, express transports, and backlog costs. It could be suitable to let the size of the SS vary throughout the different periods to keep costs low. Different sizes of SS through the value-adding stages could also be beneficial. For finalised goods sold to customers which either are being sold in large volumes or contribute with high margins, a higher stock could be motivated. The SS for items within production can widely differ depending on the item. For key items used in convergence points, where multiple items emerge into one, shortage costs are high even if only one or two items are missing (Jonsson & Mattsson, 2009). In these situations, a higher SS is suitable, while less frequent items motivate a smaller one to keep warehousing costs low.

2.4 Capacity planning

The goal of all manufacturing plants is to transform items from raw material to finished goods through applying value adding activities. To succeed a key component is to ensure enough capacity to meet the demand. However, all production resources used in this process are associated with a cost, both when used and not. There are also costs related to lost sales due to the required capacity not being met in time indicating the importance of balancing supply- and requirements of capacity. Capacity planning is a comparison between the need for capacity and the available capacity (Jonsson & Mattsson, 2009). The balancing process entails adjustments of either supply of capacity or the demanded capacity until they are equal. Supply of capacity means both the time and size of the volume. In other words, it is essential to both look for how much capacity is available but also when in time it is needed.

2.4.1 Capacity Measuring

Capacity can be measured on a single machine, manufacturing cell, or even a work center, and is measured as either volume capacity, throughput capacity, or both (Jonsson & Mattsson, 2009). Volume capacity states for a certain time period how many capacity units such as hours, the decided resource unit can achieve. Throughput capacity on the other hand expresses how many hours is possible to reserve for a given resource unit to perform a certain manufacturing operation (Qarahasanlou et al., 2022). When referring to demand of capacity both the concept capacity requirements and current workload occur. Meaning what is in progress and what is needed and not started, involving the required capacity to also handle production plans, not only released orders.

Deciding the measurement unit for different work centers or machines depends on the environment. Two commonly measured units are machine-hours and man-hours which both measure how much the respective manufacturing unit can produce over a predetermined time period. Which measurement unit is most applicable depends on whether the production is machine or labor-intensive (Jonsson & Mattsson, 2009). Furthermore, nominal capacity accounts for the number of machines and shifts, hours per shift, and number of working days when calculating the possible volume to produce. However, indirect time losses such as starvation, and capacity losses such as machine breakdowns or maintenance also need to be accounted for to achieve an accurate picture (Kiran, 2019). Also non planned operations in terms of re-prioritised rush orders or re manufacturing of broken goods might be required. When taken this into consideration, the net capacity is received and it refers to the capacity available to perform planned operations.

2.4.2 Capacity Strategies

Imbalances in demand and thus capacity changes will always exist creating difficulties in planning. It can be handled by managing the stock size in MTS environments or by adjusting the backlog size in MTO environments (Jonsson & Mattsson, 2009). The two main strategies are lead- and lag strategies. Lead strategy is a proactive approach, increasing or decreasing the capacity before demand changes striving to gain customers through shortening the lead times (Kiran, 2019). When demand rises this strategy offers volume flexibility, increasing the odds of gaining market share at the expense of higher invested capacity risk. However, when demand falls the strategy entails a higher risk of capacity shortage thus minimising the costs for unutilised capacity. Lag strategy on the other hand offers the opposite, acting as a reactive approach ensuring no investments in capacity is done before an actual demand change is real. When demand rises volume flexibility is limited forcing the company to rely on stocks or changes in delivery time. Meaning often stock levels are higher or backlogs are longer in such environments.

Furthermore, it is also possible to adjust the capacity utilisation by working with a mix of level strategy and chase strategy (Jonsson & Mattsson, 2009). A levels strategy simply means that the production volumes over a set amount of planning periods is smoothened out to the same amount produced every period. However, it is important to not allow negative inventory levels at any specific period. Advantages generated by utilising this method is that no overtime, underemployment, or subcontracting is necessary. On the other hand, disadvantages related to stock levels that have to be built up during periods of low demand leads to high inventory costs. On the other end of the spectrum is as mentioned the chase strategy where capacity is completely adapted to the demand. This does not require any stock levels except the cycle stock used in MTS. The advantages and disadvantages are the inverse of the level strategy.

2.4.3 Capacity requirements planning

Capacity requirements planning (CRP) is used in the order planning level and has its basis in manufacturing orders providing detailed plans for individual workstations or work centres. Two different variants of CRP scheduling are usually applicable to choose from. The first one is forward scheduling, planning orders based on the start time received by the material planning. Future orders start successively after the first order is finished when cautions to a safety time is taken which includes the previously mentioned information such as transportation time (Jonsson & Mattsson, 2009). As a result, the system reserves the earlier possible date for the regarded operation. According to Kalinowski et al., (2018) this is often applicable for urgent orders, meeting a narrow deadline but it also allows the planner to see real dates when new orders can be completed in a system full of running orders. However, the downside with this method is that scheduled finished time may not align with the manufacturing orders planned finished time. This is because lead times may vary and the size of the order might have been changed.

The second one is backward scheduling where the order is scheduled to be completed as close to the delivery date as possible (Kalinowski et al., 2018), this is done through calculating the latest possible time to start the order. Using this approach allows a smaller inventory since the item is completed when needed, later purchases of material, and later in-deliveries. Just as with the forward scheduling, the backward approach also considers the transportation time and queues, allowing a more accurate plan (Jonsson & Mattsson, 2009). However, the risk of receiving different starting times from the first operation and the manufacturing order is active.

2.5 Production and inventory strategies

According to Jacobs et al. (2018), demand management must align with a firm's strategy and capabilities. A key concept is the customer order decoupling point (CODP), which is when the demand shifts from customer driven (independent), to firm-controlled (dependent). Where this CODP is set, determines how production and inventory are managed. Meaning that before the CODP, production is based on forecasts, while after the CODP, it is driven by actual customer demand. By shifting the CODP forward, companies can delay activities such as manufacturing, packaging, and distribution until an order is placed, balancing efficiency and customisation. Therefore, the CODP position affects lead times, inventory levels, and production flexibility. There are many firms who choose a single CODP to operate in, but many also integrate multiple CODP’s to align their company with their customers' expectations.

2.5.1 Discrete production strategies

In a make-to-stock (MTS) environment, the organisation follows a forecast and produces finished goods to a stock. The primary focus is on maintaining the finished goods inventories, this makes the service level depend on if the item is available in stock or not. The CODP in this environment is the finished goods inventory, this makes the company follow a forecasted demand in production. One of the main challenges in a MTS environment where you produce to stock, is how much should be in stock. A high inventory will increase the service levels as the products will be available but it does also result in a very high inventory carrying cost. Therefore, it is crucial to assess the importance of both service level, and costs. In order to minimise the drawbacks of the trade-offs, changes can be made to better the estimates of demand, streamlining the logistics, and streamlining the manufacturing (Jacobs et al., 2018). A MTS system is very effective for products with stable demand where the demand pattern is predictable. Also items produced with high volume are good since small changes will have small effects. Products which benefit from economies of scale, where large batches are used , are good for such environments. Also products including low customisation that are standardised fits well since the demand variation will be lower. Lastly, spare parts are also useful to not interrupt the flow in production and disrupt the planning schedule made (Jacobs et al., 2018).

Another method is assemble-to-order (ATO), also referred to as hybrid production where the products are assembled based on customer specifications using pre-manufactured modules/components. This method allows for a high degree of customer specification while still maintaining efficiency in production and its related processes. In ATO, a critical aspect is configuration management, which means defining the customer’s orders in components and modules that are suitable for several finished products. Some combinations may be impossible or very hard to manufacture and might therefore require different modules. To ensure viable product configurations and accurate delivery times for ATO to work well, clear communication between the company and the customer is crucial. One of the primary advantages of ATO is the decrease of finished inventory stock which usually ties up a lot of capital but also space. This decrease instead allows for an increase in modules and components which often is cheaper due to fewer value adding steps have been carried out. Additionally, managing the demand of a smaller number of standardised components is much easier than managing the demand of all products with different modifications. Lastly, as ATO follows the lean manufacturing principles to streamline production processes. By reducing the production time, this method offers quicker deliveries than other methods where products are made to order (Jacobs et al., 2018).

2.5.2 Hybrid production strategies

According to (Jonsson & Mattsson, 2009), Make-to-order (MTO) and Engineer-to-order (ETO) are suitable for the most complex final products. Not only is the finished product unknown before the order but also its materials and modules. Additionally, the planning work including engineering work for customer specific modifications are also unspecified. ETO involves products that are not predefined, and the modules used in manufacturing are often developed specifically for each individual order. Both of these CODP's are vulnerable for high volume and standardised products but also when short lead times are critical. MTO is however more suitable for moderately complex products that allows some degree of customisation. This aligns with Rodrigues & Oliveira (2010), as ETO suits better for when the products are highly complex and require engineering and designing.

2.6 Standardisation

Standardisation is the process of both developing and implementing standards for processes in order to improve compatibility, efficiency, and quality in organisations. According to Jonsson & Mattsson (2009), standardised planning reduces uncertainties and inefficiencies by making sure that production, planning, and logistics follow established standardised processes. Standardisation in regards to production is best suitable in an MTS environment where finished products are known and its processes fully established. Nonetheless, according to Särkisilta (2021), standardisation is applicable and suitable to some degree for other environments e.g. MTO and ETO where structured planning frameworks can significantly increase efficiency. Katalinić (2012), strengthens this by highlighting that standardisation can improve quality and increase cost savings through usage of preassembled components and optimised designs. This can be done by facilitating the use of pre-assembled components, optimised designs and the usage of postponement.

Regarding standardisation in planning processes, Goel et al. (2023) mentions business process standardisation (BPS), which is defined as the integration and alignment of business processes that enhances efficiency, consistency, and quality. By standardising processes, organisations can reduce variability by performing more consistent execution and create better coordination among different departments. It is however important to find a balance between standardisation and flexibility as too much standardisation can lead to the organisation becoming too rigid, which limits its ability to adapt to market changes. Therefore, a successful implementation of BPS often involves selective standardisation, where core processes are standardised while allowing flexibility in areas requiring customisation.

2.7 Cross-functionality

Cross-functionality is according to El Amrani et al., (2006) how well the different company functions are integrated and aware of the coordination between them. It enables working to achieve company goals and providing clear role descriptions, enhancing collaboration in order to reduce overhead costs and cycle times.

Furthermore Pinto (2020) states that cross-functionality enables organisations to break down traditional silo-cultures, fostering effective communication, improved decision-making and performance. This ensures alignment toward common organisational goals, this is especially important in complex organisations with interdependencies between functions. According to Santa et al., (2023) organisations with a well functioning cross-functionality often generate more innovative ideas providing creative solutions.

2.7.1 Challenges of cross-functionality

According to Pinto (2020), one of the most significant problems in organisational cross-functionality is the risk of departments working in isolation to each other. Isolated working often results in employees becoming too focused on their own work only, failing to care for the need for other teams. When employees fail to work across functions, the organisation may experience misalignment, delays, and a lack of coordination. Another problem with poor cross-functionality is a lack of responsiveness and adaptability to shifts in the market which could be either opportunities or threats. In these organisations, communication follows hierarchical paths rather than across functions, resulting in bottlenecks, slow decision-making, but also neglection of innovation in the organisation.

The culture of the organisation plays a crucial role in how the employees engage in collaboration. It influences how likely they are to prioritise collective goals of the organisation instead of individual or department specific. Organisations express their commitment to cross-functionality through various symbols and shared practices to adopt a cooperative mindset and prioritise teamwork across the organisation. This can however be counteracted by poor communication, which can arise for several reasons. One common issue is a lack of clarity regarding team roles and interdependencies, making employees uncertain about whom they should share information with. Additionally, some individuals may keep some information private to maintain influence and have an advantage to get prioritised (Pinto, 2020).

2.7.2 Achieving cross-functional cooperation

There are generally four different factors influencing the cooperation in an organisation and thus the behavior of the employees (Pinto, 2020). Those critical factors are rules and procedures, accessibility, superordinate goals, and physical proximity. This affects both the psychological outcomes which strongly connect to the performance of the team, and in turn the task outcomes, ensuring a well delivered project. A superordinate goal is of the higher kind applying to more than one function. It requires the efforts and resources of multiple groups to jointly collaborate in order to reach the common goal. An important aspect is to structure the superordinate goal so that it does not replace the sub-projects own goal but connect the different goals into a bigger meaning. This intends to help teams to coordinate their efforts to jointly fulfill the larger goal since all members are needed.

2.8 Transformation of production system

This sub-chapter presents previous findings on case studies conducted related to relevant literature. Several cases are described regarding their scenario, application to the case company, and the key findings made.

2.8.1 Segmentation

Perona et al., (2009) argues that the first thing to do in order to transform from a fully MTO structure towards a hybrid structure is to conduct a segmentation of all products. The segmentation in this scenario conducted on a manufacturing company was based on order frequency and order volumes. Those axes generated an ABC classification enabling the grouping of products based on their attributes. This generated five groups where additional attributes also were included such as degree of customer specification and amount of customers buying that specific product. Group 1 consists of products with a high volume and a high order frequency delivered to multiple customers. Group 2 consists of high volume but low order frequency where the products are customer specific, often only bought by one customer. Group 3 and 5 have a low and irregular demand meaning both frequency and volumes are low. The difference is that group 3 is considered to have a bit more stability and regularity compared to group 5, even if they are grouped together. Group 4 is an additional group represented by products sharing common intermediates. Based on this the conclusion that Group 1 and 2 products should apply the MTS structure, group 3 and 5 should apply a MTO while group 4 is most suitable for hybrid (a make-to-stock, finish-to-order) structure. In summary products characterised by a frequent and stable demand and a low degree of customisation fits for a MTS strategy.

Jeong, (2011) proposes another way of determining whether products should be produced with a MTS strategy or MTO. It uses a P/D ratio which stands for production lead time and delivery lead time for each product. This then needs to be combined with a relative demand volatility score. If the P/D ratio is less than one meaning that the production lead time is less than the delivery lead time a MTO is most applicable. However, if the relative demand volatility is low a MTS strategy could also be considered. In cases where the P/D ratio is greater than one the MTS should be applied, but as was the case last time if the demand volatility is high a MTO might be better to consider. This in turn acts as the starting point to determine the optimal decoupling point.

Pereira et al. (2022), conducted a study in collaboration with a cable manufacturer operating in two factories which took another approach. The company produces both standard MTS products and highly complex and customised MTO products. The study developed a model to balance cost, service level, and inventory where different strategies were tested. This approach incorporated multiple planning levels, including MTS/MTO partitioning, capacity coordination, and production scheduling through a mixed-integer linear programming model. The study highlights cross-functional Sales and Operations Planning (S&OP) meetings as a key element in optimising decision-making. These meetings involve teams from procurement, production, logistics, and sales, ensuring an integrated approach to planning. The planning department plays a crucial role in mediating these discussions by gathering data and generating plans for review.

Furthermore, Pereira et al., (2022) continues by segmenting products based on their characteristics and market demands. It defines product families to achieve the highest consistency between marketing and production where one approach is to categorise products based on their production processes. By identifying the products' respective production processes, it identified that bottlenecks were not always fixed but varied depending on forecasted demand and incoming orders. To manage these constraints, the company adopted a hybrid planning approach that allowed flexibility in scheduling and resource allocation. The study explored solutions such as overtime, subcontracting, and optimised machine allocations to mitigate bottleneck effects and ensure smoother production flow.

Rafiei & Rabbani (2014) present another method for segmenting products into either MTS or MTO production strategies. Their case study focuses on Company X, a leading home appliance manufacturer in the domestic market. The study classifies products into different production strategies based on five key criteria. The first criteria is modularity, which refers to the extent to which products are composed of independent modules. Secondly is commonality, which measures the proportion of shared components between products. Third is Compatibility, assessing technological and marketing alignment. The fourth criteria is reusability, indicating how existing parts can be reused in new products. Lastly, demand behavior, considering customer order patterns that influence product grouping.

2.8.2 Decoupling point

The second step in transforming towards a hybrid structure is to determine the optimal decoupling point for each flow. Perona et al., (2009) states that the decoupling point refers to the position where the products are linked to a customer order. Meaning before the decoupling point the production flow is produced against a storage and afterwards it continues the production phase towards a specific customer order. Therefore a separation of MTO and MTS is generated. Depending on the placement, the lead times, inventory cost and production efficiency is determined. Products that were classified in either group 1 or 2 using a MTS structure where the demand is more predictable the decoupling point is held downstreams closer to the customer. Group 3 and 5 on the other hand are products represented by a more unstable demand and therefore the decoupling point is moved further upstreams towards raw material level. More interesting is group 4 where products share the same intermediaries and therefore it is recommended to also place the decoupling point at the intermediary level. This resulted in if a movement of the decoupling point was conducted downstreams the customer responsiveness increased but the inventory cost also increased and vice versa.

Aligning with the study conducted by Perona et al., (2009) is the study made by Jeong, (2011) where a decoupling point is described as the push-pull boundary separating forecast driven production and customer order driven production. Upstreams the production is based on forecasts where the common production strategy is MTS and downstreams is the customer order in charge usually collaborating with MTO. The determination of the optimal decoupling point was conducted by using mathematical simulations. If the decoupling point was moved backward in the supply chain towards raw material the response time towards customer decrease and the manufacturing efficiency improves while the decrease of WIP and increase of product customisation see Table 1 below.

Table 1: Illustration of decoupling point variables and evaluation (Jeong, 2011)

Area of impact	Move decoupling point upwards	Move decoupling point downwards
Response time to customer	Increase	Decrease
Manufacturing efficiency	Worsen	Improve
WIP/inventory	Decrease	Increase
Product customisation	Increase	Decrease

2.8.3 Lot size determination

The third step of the transition is to determine the optimal replenishment system for each product group. Perona et al., (2009) suggest that group 1 with a regular demand should use a strategy which has a fixed order interval and a varying order quantity to ensure that the stock always is ordered to a certain predetermined level. Whereas products within group 2 should be considered in collaboration with the customer since there often is very few customers, but still a set time interval and varying quantity. Regarding group 3 with pretty low sales, and only some regularity the replenishment should occur from the customer order since a MTO strategy is used. However, the minimum production quantity acts as the EOQ, meaning it is not economically to order fewer than the EOQ. In other words, it can be beneficial to order a bit more than the customer demands to save on changeover time and cost. The same argument goes for group 5 just that here the L4L strategy is even more applicable. Group 4 is suggested to use either EOQ or L4L depending on where in the intermediary chain the decoupling point is. If it is closer to finished goods a L4L is applied, if it is the opposite the same strategy as group 1 products is used.

2.8.4 Capacity allocation

Rafiei & Rabbani, (2011) proposes a model to determine how to prioritise the capacity in situations where it is limited in a hybrid production structure. This requires a segmentation which is already presented where products are divided into MTS, MTO, or hybrid products. Also previously mentioned decoupling points need to be decided for each product family. When this is conducted the prioritisation begins. MTS products are constantly produced when possible, meaning only MTO products are prioritised. The prioritisation is based on four different criterias which are ranked as either high or low. The first criteria is customer profit contribution, meaning the financial value the customer is contributing with. The second one is the potential purchasing of the customer, referring to the long term collaboration and how likely they are to buy more in the future. The third criteria is regarding the order size where larger orders are more economically beneficial to produce and should be prioritised. The last criteria is order purchase range also called product mix. If the customer buys a wider range it is more complicated to produce. All those four criterias get ranked from low to high and receive a summarised score see Table 2, working as the prioritisation list.

Table 2: Rafiei & Rabbani, (2011)

Criteria Score	Order rank
L,L,L,L	Low
L,L,H,H	Medium
H,H,H,H	High

When the score is received it is possible to allocate the initial capacity. According to Rafiei & Rabbani, (2011) the order with the highest score should be prioritised first and receives enough capacity to be completed in time. To do this the expected required capacity for each order is calculated based on order probability of acceptance and historical data alternatively expertise. By doing this the most important customers will always receive their products as agreed. Thirdly, when all MTO orders are ranked it is time to focus on the products classified as either hybrid or MTS. Since those are based on forecast to some extent this prioritisation is needed in the lot-sizing and capacity allocation steps. Since there are no customer orders behind the production it is important to produce a well thought through amount.

It uses three new criterias which are estimated contribution, reputation, and potential future sales (Rafiei & rabbani, 2011). The reputation stands for how important the product is for the brand image. This is later evaluated on three levels: top, middle, and bottom, reflecting overall production value, the three criterias and the product families in that order. So each product family is being evaluated against all three criteria through pairwise comparisons. For example, is product family A more important then B in terms of criteria 1,2, and 3. Then scores between 1-9 are assigned where the values are used in the lot-sizing model later. A higher score means a higher priority regarding the top level of the product tree.

Step four concerns the determination of lot size for MTS and hybrid structured product families. It is evaluated based on a couple of criterias with the goal of minimising costs at the same time as always fulfilling the forecasted amount. The criterias are according to Rafiei & Rabbani, (2011) production cost, setup cost, holding cost, backlog cost, production value, warehouse capacity, and resource capacity. Lastly, based on all received information a well informed decision whether the order should be accepted or not can be made. Simplified the order can be separated into two categories: negotiable orders and non negotiable orders. The process for both are similar but if the orders are negotiable if capacity is not available the goal is to postpone the order until free capacity is identified. When orders are requested from a customer the first step is to check inventory levels for MTS and hybrid products. If it is a MTO it follows the previously described process. Then a calculation based on the last due date and lead time is conducted. Afterwards check the rough-cut capacity planning, if orders can be completed with regards to capacity constraints the order should be accepted. Otherwise reject if the order is non negotiable.

2.8.5 Implementation impact

Pereira et al. (2022) observed several key improvements as a result of implementing the hybrid production approach. Cost savings of up to 10% were achieved by

optimising batch sizes and reducing production costs. Additionally, operational efficiency improved as the model allowed for dynamic lot-sizing rather than fixed batch sizes, leading to better inventory management and reduced lead times. The study also demonstrated that optimising production scheduling by considering both MTO and MTS states resulted in up to 25% additional cost savings compared to single-strategy approaches. This in turn improved the balance between MTO and MTS, leading to better stock availability and reduced lead times.
Furthermore, the hybrid model enhanced responsiveness, this was especially notable when total demand was around 90% of production capacity, which ensured a more efficient allocation of resources. These findings highlight the potential effects of a flexible production strategy to improve cost efficiency, stock availability, and scheduling effectiveness.

The linear programming model presented by Rafiei & Rabbani (2014) showed significant improvements to customer satisfaction and easier line management due to improved material and data flows across the segmented product families. Better order partitioning significantly enhanced the capacity management and therefore shortened order lead times greatly. Quantitative analyses comparing data from a 90-day period before and after implementation showed improvements in inventory planning, order adherence, and lead time. The quantitative results showed a decrease in backordered quantity by 83%, an increase on delivered orders in time by 20% and a reduction on the average lead time by almost 47%.

Rafiei & Rabbani, (2011) noted several positive outcomes from the case study conducted on a wood company facing long lead times, multiple missed due dates, high cost and overall overuse of capacity. The company used a hybrid structure where both pure MTS, pure MTO and a combination of both existed in parallel. First it can be seen that on-time deliveries increased, and nearly doubled in amount. The backlog got completely reduced just as the inventory shortage for semi finished goods. Also the overtime caused by too much planned capacity was reduced by 75%. The only downside was that the amount of orders was slightly reduced and described to be around 20% along with longer set up times.

From the Perona et al., (2009) study conducted on a manufacturing company transforming from a pure MTO to a hybrid structure multiple findings were presented. By conducting a segmentation of products, determining an optimal decoupling point and an appropriate lot size it was possible to achieve a much higher delivery precision of the products which transformed towards MTS products. However, the cost for this was an increased inventory level and thereby a higher holding cost. Products which received a lower classification saw an increased delivery precision from 25% to 75%. This since they partly were delivered from stock due to a hybrid structure reducing delays and long lead times. Also in total the average cost decreased with 36% through balancing the holding cost and set-up cost.

The study conducted by Jeong, (2011) which proposed a way of conducting the segmentation and focused on finding the optimal decoupling point only had few findings. The first is that if the forecast did underestimate the actual amount the production rate increased over time and the inventory level started low and increased by time. When the forecast overestimated the inventory increased early on and then by time adjusted downwards. Also the obvious that if the forecast overestimated the total holding cost was higher but the backlog cost was lower and vice versa.

Table 3: Previous case studies conducted in similar environments and their results

Area	Article	Impact
Segmentation	Perona et al., (2009)	• Higher delivery precision • Decreased cost with 36 %
	Jeong, (2011)	• Forecast overestimated - inventory high early • Forecast underestimated - inventory low early
	Pereiraa et al. (2022)	• Cost savings by 10-25% • Reduced lead times
	Rafiei & Rabbani (2014)	• Reduced average lead time by 47% • 20% increased delivery precision • Reduced backorder log
Decoupling point	Perona et al., (2009)	• Higher delivery precision • Decreased cost with 36 %
	Jeong, (2011)	• Forecast overestimated - inventory high early • Forecast underestimated - inventory low early
Lot size	Perona et al., (2009)	• Higher delivery precision • Decreased cost with 36 %
	Rafiei & Rabbani, (2011)	• On-time deliveries doubled • Erased backlog • No shortages for SFG • Reduced overtime • Reduced order intake
Capacity allocation	Rafiei & Rabbani, (2011)	• On-time deliveries doubled • Erased backlog • No shortages for SFG • Reduced overtime • Reduced order intake

3. Methodology

This chapter presents the research approach for conducting the study, outlining the methodology used. It provides a detailed explanation of the various methods used for data acquisition and analysis, ensuring a structured and systematic investigation. The chapter also discusses the rationale for the chosen methods to ensure reliability and validity of the findings.

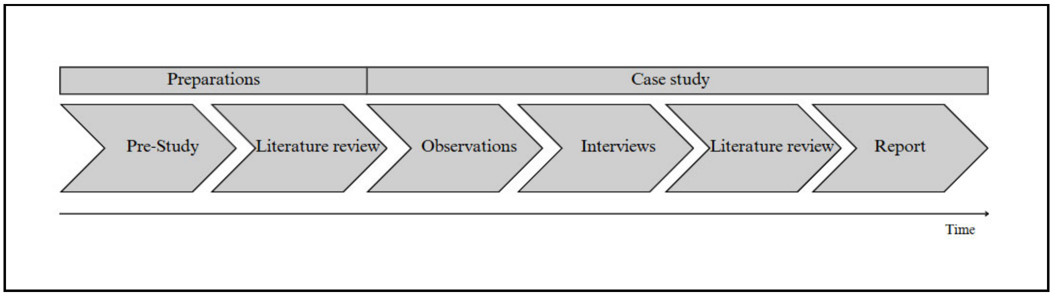

Figure 4: Illustration of the workflow

3.1 Pre-study

At the start of the project, an explorative pre-study was made where the authors were introduced to company Alpha through an onboarding process. This included receiving access to several documents, systems, and an introduction to relevant managers to get an understanding of company Alpha's operations and structure. Additionally, this helped refine the study's scope and aim by identifying areas of interest. The report was continuously reviewed with input from the authors' supervisor at Chalmers and at company Alpha to ensure the report's alignment with its established objectives, as well as its academic and organisational expectations. Additionally, inputs from other students involved in the later described seminars were considered.

3.2 Literature review

A literature review was conducted to find existing knowledge regarding the key topics of the project. In order to find this literature, research databases such as Google Scholar, Scopus, and Chalmers Library were used. Keywords for the research include Material resource planning (MRP), lot size, capacity planning, standardisation, make-to-stock, and hybrid production structure, make-to-order, decoupling point, cross-functionality, manufacturing industry. As the study progressed, additional keywords emerged and were incorporated into the search. The literature review was primarily performed at the start of the project, but has been ongoing throughout the entire study as new information has been acknowledged. All selected articles used have been peer-reviewed to assess the credibility of the paper (Uppsala University, 2024).

3.3 Case study

A case was used in this study as it offers in-depth analysis by providing a detailed examination of the current situation in its real-world context (Yin, 2018)(Crowe et al., 2011). A case study aims to identify a research gap and propose research questions (RQs) to bridge that gap. This is achieved through theory building, where proposed solutions are developed based on existing strategies (Eisenhardt & Graebner, 2007). Case studies are a great method when addressing research questions that aim to answer "what" and "why" (Yin, 2009), making it appropriate for answering RQ two and three regarding the transition phase. Additionally, according to Eisenhardt & Graebner (2007), this approach is especially valuable in cases where research findings must be both academically relevant and practically actionable.

A case study approach, as described by Patel & Davidsson (2019), allows for a holistic examination of an organisation's processes and structural transitions. This aligns with the objective of this research, which was to analyse the current production and planning structure at Company Alpha and propose potential improvements. By gathering detailed qualitative data, this study provided insights into the operational challenges and opportunities associated with planning transitions, both from a theoretical and real-world perspective. Furthermore, a case study explores the problems from different angles through obtaining richness by conducting a deep dive into the subject. The main reason why the case study was considered throughout this report was that the potential transition proposed by the company is not a common strategy within the manufacturing industry. Therefore, only using theoretical frameworks would not provide a thorough analysis. Additionally, this thesis will help guide companies through similar transitions.

However, a case study entails risks that can cause negative impacts on the study if not considered. Crowe et al. (2011) explain the potential risks and how they can be mitigated to reduce or negate the impact of these risks. The first risk is a lack of thoroughness and for being difficult to generalise. This can be counteracted by using respondent validation, where participants review findings for accuracy, triangulation of data, and theoretical sampling. Secondly, there is an ethical risk, stating that the anonymity and confidentiality can be breached. To prevent this, it is important to provide participants with sufficient information. Thirdly, the risk of integration with the theoretical framework exists. If too much theory is considered, the risk of abandoning the case scenario increases. To prevent this, formulate open questions that allow the participants to speak freely about their interpretations, and do not force the company into a theoretical framework. The fourth risk is regarding difficulties in defining and following the scope, and the fifth risk regards excessive or insufficient data collection. To prevent both risks, ensure a clearly defined scope, timeline, subjects of interest, and research questions.

3.4 Data acquisition

To ensure a comprehensive understanding of the current planning and production setup, data will also be collected through internal and confidential company documents. Sources included numerical data, reports, PowerPoint presentations, and other relevant data sources. This data was anonymised by assigning code names and applying a factor to relevant values to maintain confidentiality. Analysing these sources helped triangulate the data gathered from interviews and observations to give a more holistic view of the planning processes. An important note is that all involved employees have been anonymised to ensure confidentiality inter- and intra-organisation. Using multiple data sources will improve the validity and reliability of the study by verifying information, which provides help when identifying potential discrepancies or patterns that might not have been found through single data collection methods (O’Cathain et al., 2010). While triangulation was an essential part of the research process, it has not been documented but it was done continuously throughout the report to make sure that all analyses made were accurate.

3.4.1 Observations

Direct observations have also been used as a qualitative method and acted as a complement to the interviews to give a broader understanding of the current situation at the company (Bryman, 2018). This method can reveal information that might otherwise remain hidden while also reducing potential biases from interviewed personnel (Justesen, 2011). In this study, observations were done within the production facility and the planning department. This gave a deeper understanding of the respective processes and their relation to each other which was needed to assess potential results of future suggested implementations. All observations were done with the participants' consent and efforts were made to minimise potential disturbance to their daily operations. Table 4 below describes which observations have been conducted, which case it is connected to along with the subject’s position and description, and lastly, the goal of each respective observation.

Table 4: Observations conducted on the respective cases.

Case	**Type of position**	**Description**	**Goal**
Case A	Product planner	Product Planner A	Identify work tasks
Case A	Production planner	Production Planner A	Identify work tasks
Case A	Production line A	Line A	Map the production
Case B	Product planner	Product Planner B	Determine products to investigate
Case B	Production line B	Line B	Map the production
Case A&B	Project planner	Project Planner 1	Identify work tasks
Case A&B	Sub-project leader	Sub-project Leader 1	Identify work tasks
Case A&B	Project planner	Project Planner 2	Visualise the project structure

3.4.2 Interviews

During the course of the project, semi-structured interviews were held with a broad range of company personnel, including product planners, production planners, project planners, and sub-project leaders. The interviews were held as they are a qualitative research method that combines predetermined questions but also has the flexibility to delve deeper into questions that arise during the conversation (Kallio et al., 2016). This allowed the participants to elaborate on their perspectives and experiences, resulting in more detailed information that otherwise might have remained covered. Therefore, this provided deeper insights while still remaining consistent across all interviews (Bryman, 2018). The interview's primary objective was to find problems and opportunities within each respective part of the production planning process. To give an instance, interviews held with planning personnel closer to the production addressed questions regarding the production area, while interviews with planners further away addressed questions aiming to answer more planning-related subjects.

With the interviewees' consent, all interviews were recorded and carefully listened to afterwards with the purpose of gathering quotes to strengthen arguments. This resulted in a more accurate representation of the responses and allowed the interviewer to focus fully on the conversation without the distraction of keeping up with note-taking (Flowerdew & Martin, 2013). Table 5 below describes which of the two cases the interviewees adhere to, being case A for production line A and case B for production line B. The table also describes the type of position the interviewee had, what the interviewee will be referenced as in the study, as well as the length of the interviews.

Table 5: Case and respondents

Case	Type of position	Description	Interview duration
Case A	Product planner	Product planner A	1h 3min
Case A	Production planner	Production planner A	40 min
Case B	Product planner	Product planner B	53 min
Case B	Production planner	Production planner B	42 min
Case A&B	Sub-Project leader	Sub-project Leader 2	49 min
Case A&B	Project planner	Project Planner 3	51 min
Case A&B	Project planner	Project Planner 2	35 min

When assessing the importance of the identified problems and potential improvement areas, a meeting was conducted with an experienced manager at the company. The purpose of this meeting was to gain insights into both the feasibility of implementing the proposed improvements but also the potential impact they could have on the organisation as a whole. While it would have been ideal to include a broader planning group in the assessment to get more and diverse perspectives, time constraints and limited availability of key stakeholders made this unfeasible during the project period. However, with the interviews conducted, it is believed to have captured all perspectives from the planning roles, which in turn have been considered when evaluating the potential impacts. To ensure that participants felt comfortable and could speak freely about challenges, inefficiencies, but also potential improvements, all interviews and observations have been conducted anonymously, strengthening the ethicality. No names or identifiable details have been presented in the report, which has allowed participants to express their opinions without concerns about consequences such as fear of exposure or discrimination. Furthermore, participants were informed of the freedom to walk out at any time during the interview.

Anonymity in qualitative research has been shown to increase the reliability and validity of responses (Laryeafio & Ogbewe, 2023).

3.4.4 Reliability and Validity

Ensuring reliability and validity is crucial for gaining credibility and accuracy of the research's findings. Reliability refers to the consistency and dependability in order to recreate the data collection and analysis process. Therefore, if a study yields consistent results by applying the same methods while having similar conditions (Bell et al., 2022). In order to enhance the reliability of the study, it has used standardised procedures for data collection, e.g., semi-structured interviews and observations with documentation, which has minimised the risk of subjective interpretation. To further minimise the errors, both authors have been present during the interviews and observations, ensuring a shared understanding and reducing individual biases. Validity, on the other hand, according to Bell et al. (2022), refers to the degree to which the study accurately measures what it is intended to measure. Accurate validity ensures that the chosen methods address the research questions and that the findings reflect real-world conditions. To strengthen validity, the study has incorporated triangulation, using multiple data sources, e.g. interviews, observations, and data analysis to cross-verify results. Furthermore, aligning the research with established theoretical frameworks helps ensure that the conclusions drawn are applicable to the context.

3.5 Seminar

This thesis has undergone a thorough and continuous review throughout the course of the study. Three presentations were conducted for a broader audience, including professors with expertise in relevant subject areas, as well as students writing their own theses. These sessions included formal opposition, where both the presentation and the written report were critically evaluated. Feedback covered a wide range of aspects, including the structure, scope, methodology, theoretical framework, and clarity of the analysis. The insights gained from these sessions have been carefully considered and integrated to improve the overall quality, clarity, and thoroughness of the thesis.

4. Case company structure

This section will present the findings from the observations answering research question one. Providing insight into the four different types of planning roles within the organisation: sub-project manager, project planner, product planner, and production planner. Explaining their roles, responsibilities, and working procedures as well as visualising the two different project structures, explaining how the roles interact in different planning environments. Also providing visual pictures of how the production lines A and B are set up, explaining how the respective products are manufactured. In each production line, three different products were studied, meaning in total six products will provide the input for the pictures generated of each production line.

4.1 Definition of Project-based and Product-based Production Planning

Project-based planning in regards to the focal company is based on the customer order (CO) which creates a main project in the organisation. This is broken down into smaller sub-projects distributed to the different departments until a reasonable project size is achieved. This means that one person can be responsible for the project ensuring the agreements are met. These smaller projects in turn involve several different products that together fulfills the project. When the report is referring to project planning what is meant is the planning conducted on those smaller project levels. Product-based planning is based on a lower level referring to the planning of a single product or module which later will be assembled with other modules and materials to complete a project. The way product-based planning is desired is to follow a production schedule to be able to upkeep the inventory levels and availability of these required products. Thus, in this study, product-based planning will be referred to as Make-to-Stock whilst the current, project-based planning, will be referred to as Make-to-Order. These concepts will be further explained throughout the study.

4.2 Project structure

This chapter explores how information flows between key roles in project management, including sub-project managers, project planners, product planners, and production planners. Additionally, the chapter presents visual representations of project structures at different maturity levels, illustrating how responsibilities shift as projects progress. This helps clarify the administrative workflow and the interactions between planning roles.

4.2.1 Visualisation of project structure

The figures below present the project structure of a mature and an immature project where the larger elliptic visualises individual projects that is owned by the sub-project manager and delimits this thesis. Further in the result everything outside the elliptic will not be further addressed. As described there are two different project structures depending on the development of the project, also referred to the maturity. Projects with new products and specifications require a development phase where the project planners have responsibility across both the project and product level to ensure desired results. This since the project planner is more involved with engineering and has a longer planning horizon. In the development phase, the project planner receives information from the engineering department who designs the product that the customer has ordered. In mature projects, the responsibility across product level is instead transferred to a product planner. However, in special scenarios, exceptions can be made where the project planner maintains certain responsibilities also during the product level.

Both figures are supposed to be viewed from a top-down perspective, showcasing the administrative workflow of information and how the project work tasks align and are passed on to the different roles. Meaning the highest project level is found at the top which corresponds to the sub-project manager, who evaluates and initiates the project which ends up at the same project planner as found at the second highest level. The different elliptics represent the different roles in relation to the planning faces of a project. Where the lines correspond to how the flow of information is transferred between the roles. These lines can either be connected to a certain role being represented by an elliptic or a certain planning level which is the dashed line. If the latter scenario is occurring this means that everyone within the level communicates with the connected elliptic or level. The other dashed line between the different production lines visualises that some products are transferred in between lines for last modifications, as this extends outside of the projects scope, it will not be further addressed. Regarding the sub-project manager there are no lines connected to the lower levels within the project. However, this role communicates with all other roles since it manages the project and needs to be up to date.

4.2.2 Information sharing between roles

Each project has a dedicated sub-project manager along with a few project planners depending on the complexity of the project. This means that a sub-project manager works in synergy with more than one project planner in the specific project but also with project planners from other projects. Adding to the complexity, each project's project planners do not only work beside other project planners but also together with multiple sub-project managers across projects. Since the sub-project manager is responsible to handle the financial data across all production steps and planning roles, each planner across all planning levels (project, product, and production) will have to communicate with multiple sub-project managers from different projects simultaneously.

Each project planner required within the project is responsible to communicate with all product planners from where products are required. Meaning there will be multiple cross communications between project and product planners simultaneously. However, the complexity regarding the relationship between a product planner and a production planner is more simple. There are usually one or two product planners responsible for each production line where one production planner is in charge and responsible for all products manufactured at that site. In cases of two product planners, one is usually the main planner and the other the secondary planner. This means that a product planner only communicates with one production planner simplifying the information sharing. In other words, the product planner acts as a link between the production planner and project planner which usually should have no direct communication.

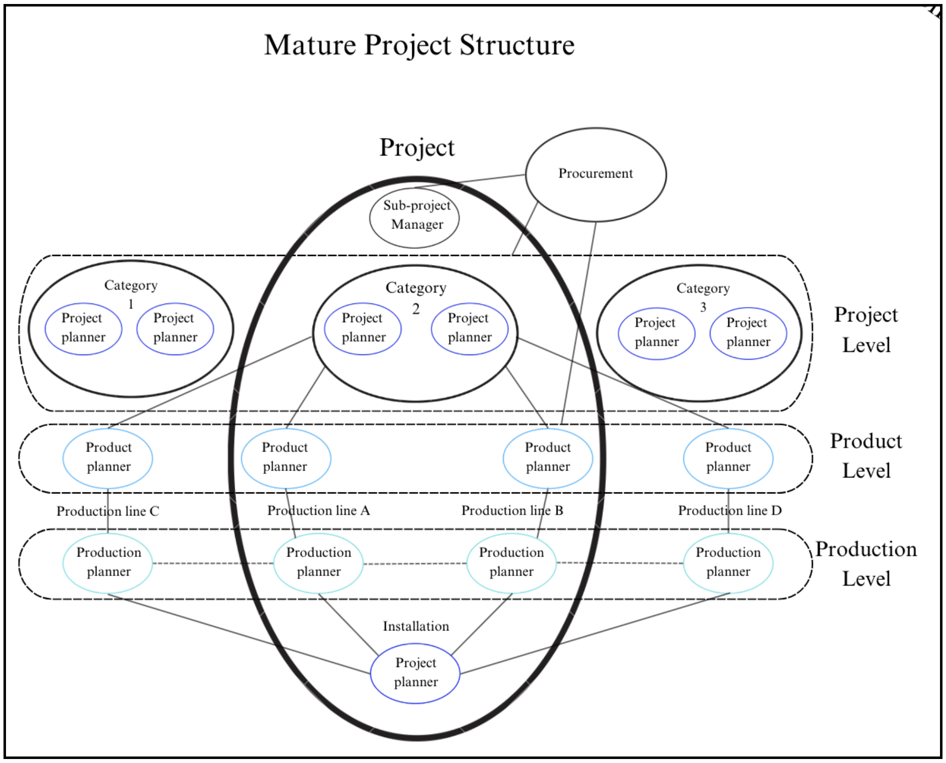

Figure 7: Illustration of a general perspective of our interpretation, on the project structure and its different planning levels and how to interact in a mature project.

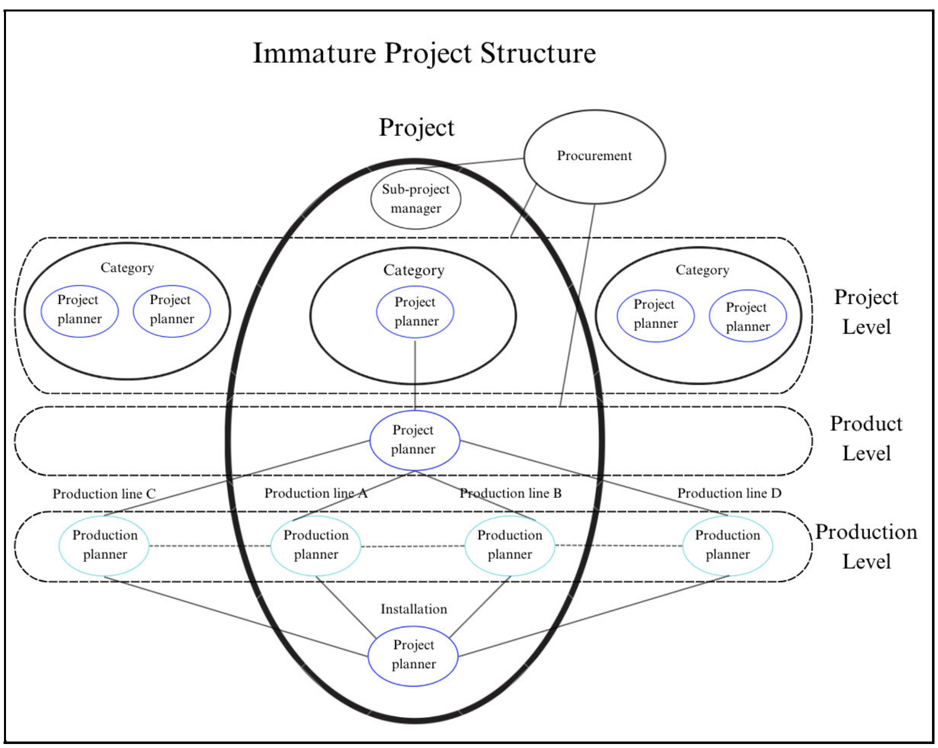

Figure 8: Illustration of a general perspective of our interpretation, on the project structure and its different planning levels and how to interact in an immature project.

4.3 Sub-project manager

The sub-project manager is the project owner and is responsible for ensuring that the project is finished and delivered to the customer as promised. However, the sub-project manager does not conduct the operative activities within the project, but rather distributes them to other roles. This can be done either within one or across multiple projects, depending on the experience of the sub-project manager. Its role is to act more as an administrative intermediary between all company planning functions connected to the project and the management. The sub-project manager is connected to the early stages of project management as well as during the course by providing financial data to help determine if and when the project should proceed. There is also a set diagram providing instructions and guidance on which areas the sub-project manager tasks occur in. The planning functions that are included in the diagram are procurement, configuration management, and finance within the scope of project management. The sub-project manager is connected to procurement mostly at the strategic level with the goal of minimising costs. However, sometimes collaboration with the operational level also occurs. This is mainly for information updates regarding deliveries to inform management, but also to handle waivers which are when deviations occur from standard purchasing procedures. When waivers occur, the procured material gets handed to the engineering department which decides if it is usable or not in collaboration with the sub-project manager.

Regarding finance, the sub-project manager is responsible to handle and spread out the manufacturing costs throughout the different modules during a project's duration. This is conducted through a breakdown of the large project into smaller sub-projects delivered by the different production lines and departments. They have an objective to lower the costs across the different sub-projects. In other words, the breakdown represents the different costs connected to the different production lines, showcasing where the money is distributed. This also includes allocating sub-products to their respective projects. When referring to configuration management, the sub-project manager is responsible to support the configuration team and update the MRP system with the latest information and documentation. It ensures technical and administrative control over a product, its configuration, related information, traceability, change control, and compliance with physical and functional requirements.

4.4 Project planner

A project planner operates in the higher planning level within the projects, referred to as the project level, and generates tasks, distributing those down to the product and production levels of the project. There is no set framework providing clear instructions on how a project planner should operate. Instead, each project is handled differently due to its dynamic nature. Especially for immature projects as the project planner communicates with multiple different roles which obstructs a clear framework. However, there are some general responsibilities and working procedures for the project planner to follow. The project management board receives the project from a customer and assigns a sub-project manager to evaluate the project, and in turn assigns the designated project planner(s) based on suitability. The project planner's assignments are initiated by the management board, alternatively from a fictive CO which is based on speculations. However, the latter scenario is highly unusual.

The project planner inserts CO’s into the MRP system which generates production plans for the specific project which is delegated further towards all affected product planners and production lines. It acts as the starting point for all planners' assignments. The plan is calculated through backwards scheduling and based on lead times and required project completion dates. This means that the project planner needs to manually manage the capacity constraints within the production lines. The responsibilities also involve investigating the inventory status and releasing purchasing requisitions when there is a need for material to ensure availability, which can be seen in the MRP system.

Regarding the communication towards procurement, it occurs in two ways. This person is partly responsible for handling the communication with the procurement department regarding the strategic level. This means that the first time a specific project is received or changes within the product level occurs, it is called an immature project which can be seen further below in Figure 8. In this case, the process towards procurement is initiated by the sub-project leader but assisted by the project planner who owns the product. The reason for this is that management wants more experienced personnel to handle immature projects as the complexity increases with more company functions involved. A project planner usually maintains closer contact with those departments in the day-to-day business, simplifying the collaboration. However, for later customer orders of similar kind, when the project is mature, this is delegated to the product planner instead, where the ownership is also transferred. The project planner also interacts across the operative procurement level in the case of material required within the higher levels of BOM regarding the end-level product. This also applies in case of changes with existing products which transform it back to the development phase, meaning the project planner received the ownership.

The project planner is also responsible for ensuring that the project follows the schedule and that all product levels are completed in time. Meaning frequent reconciliations with the product planner are required to ensure that all products from the lower levels are delivered when needed. This requires the project planner to manage occurring discrepancies, taking action such as rescheduling in order to avoid excessive costs and keep sub-project managers and in turn management informed. When all products are completed and the procured components and materials have arrived, the project planner conducts a complete reservation of all required materials in order to release the final shop order towards the assembly. Usually, a complete reservation is needed to start the assembly, otherwise, it prevents other projects from using the material. However, in special cases with permission from management rush orders can be allowed to be started as partly reserved. Meaning not every product required is available yet at the site.

Lastly, when the order is completely reserved, the project planner initiates the final assembly of the finished product, by releasing the shop order. It is released seven days before it is aimed to start in order to allow pickers enough time to collect all necessary materials and products, and deliver them to the site. A general strategy is to review the long term material requirements before releasing purchase requisitions (PR) to the procurement department. This is done to increase the bargaining power towards suppliers and utilising economies of scale.

Table 6 below provides a clear overview, summarising the project planner's general working procedures.

General order	Short description of the procedure
1. Order receiving	• Receiving an order from a sub-project manager and contacting respective product planners.
2. Project initiation	• Creating an internal order within the MRP by inserting the CO into the system, allowing the product planner to handle the shop order. • Evaluate the automatically generated production plan and delegate work to affected product planners.
3. Material availability	• Investigate the inventory status of required material from the higher BOM level. • In case of a shortage, release purchase requisitions towards the procurement department.
4. Product status	• Frequent reconciliations towards involved product planners and within the MRP system to ensure project alignment in regards to capacity management and time frames.
5. Reservation of material	• A complete reservation of all required materials and products for the order is conducted when all products are produced and all material is procured. Along with the project aligning with the right time frame according to the production schedule.
6. Final shop order release	• Release the final SO towards assembly when everything is reserved.

4.5 Product planner

The product planner works in the lower planning level of the project, referred to as the product level. Each product planner is responsible towards a specific production line ensuring a well working material availability process. The product planner receives information and the overall project's production plan which is created by the MRP system and controlled by relevant planners. This project origins from a customer order, controlled and released by the project planner. The MRP gathers information from the specific project plan and compares it with already existing plans and calculates a production plan based on lead time and the required product completion dates. This in turn requires the product planner to manually control the capacity constraints at the production line, to see if it is possible to follow or not.

The product planner is responsible for a variety of products and ensuring that they are available at the right time and in the right quantity when the project requires. However, this does not apply to projects defined as immature. The product planner's task is to check and confirm that the proposed product plan is feasible within the expected deadline and the production capacity. If the plan is not feasible, the product planner can suggest changes that need to be confirmed with management. To ensure that the material required for the project is available at the right time and in the right quantity, the product planner places purchase requisitions. The PR gets forwarded to the procurement department, where a buyer takes over the responsibility to source the required material in the specified time frame. When the material has arrived at the warehouse, it is the warehouse personnels' responsibility to ensure that the material gets properly stored along with the already existing inventory. However, the product planner is accountable for handling any defects that require making a complaint to the supplier.

When all material is stored, the product planner can reserve the material and release the SO to production. The material needs to be reserved 7 days before the SO is released, given that all required material is available in storage, otherwise it is not possible to reserve the material. In ideal conditions, everything is reserved in time, but in specific scenarios, it is possible to partially reserve. To partially reserve is to reserve the available material and start production for as long as it is possible, and when the missing material gets delivered, the production continues. However, this requires approval from the line manager and in most cases, full material availability is necessary before the SO can be released.

Table 7 below provides a clear overview, summarising the product planner's general working procedures.

General order	**Short description of the procedure**
1. Order receiving	• Receiving the customer order from the project planner through the MRP system.
2. Reviewing production plan	• A review of the production plan is done to ensure it can be followed. Otherwise it is refined and communicated to all involved parties.
3. Material availability	• Investigate the inventory status of required material from the lower BOM level. • In case of a shortage, release purchase requisitions to the procurement department.
4. Reservation of material	• When all material is available and the time of production is close, a complete reservation is done.
5. Shop order release	• When the order is reserved and the calculated production start time is reached, the product planner releases the SO.

4.6 Production planner

The production planner works in the lowest planning level of the project, closest to production, which is referred to as the production level. The production planner receives a shop order from the product planner in the organisation's MRP system when the order is completely reserved. The assignment is to initiate the picking activities to the employees in the warehouse and then demand transportation to the specific production line. In a majority of the cases, the order is completely reserved simplifying a smooth picking and production process. However, this is not always the case since a rush order might have to be started even when part of the materials are missing. In the case of broken products or missing material that is visible in the MRP system but not in reality, the production planner is responsible for generating a repair shop order or starting a troubleshooting mission. Also, if only one or two parts are missing when the production should start, there is a function available for the production planner allowing the production line to receive the missing parts within a 15 minutes break.

The production planner is only responsible for the products for a short period of time. It starts when the SO has been released and stretches until the products have begun their manufacturing process. Now, the responsibility is transferred to the line manager whose task is to have the products manufactured within the set deadline. It is the production planners responsibility to keep the project planners and product planners up to date regarding the status of the picking, transportation, and the manufacturing process of the products. In turn project and product planners inform the sub-project manager. In general the production planner is responsible to support the production line with all necessary information and ensure a smooth flow of the production.

Table 8 below provides a clear overview, summarising the production planners' general working procedures.

General order	Short description of the procedure
1. Receiving a shop order	• The SO is received from the product planner, visible in the MRP system.
2. Control reservation status	• Control whether the shop order is completely reserved. • In case of a partly reserved order, contribute to the decision-making of whether to start anyway or wait.
3. Initiating picking	• Send picking and transport orders to the warehouse personnel.
4. Managing discrepancies	• In the case of broken products or missing material, initiate a repair shop order or troubleshooting mission.
5. Report to product planner	• Provide the product planner with status updates, how the production is aligning with the production schedule.

4.7 Production

This section will present the results gathered from the observations of the different production lines. It will map the processes required for producing its respective products and present it through a visual representation and a comprehensive written explanation. The figures are a representation of the respective production line, meaning all products produced within a production line will be assumed to pass through the same kind of flow and stations.

4.7.1 Production line A

In production line A, there are mainly three types of activities performed throughout the value adding processes. Those are production, inspection and testing. With production what is referred to is that the products are being both partly assembled using different produced and bought components and partly continuously produced in terms of soldering activities and similar. The production process is initiated by the production planner which brings the material from storage up to the production line. At site A there are three different products being manufactured and those are referred to as product A, B, and C. They are all produced at the same working stations, requiring more or less the same manufacturing equipment. The products use the same equipment and therefore have similar attributes but they do differ in complexity as they contain different amounts of pre-produced sub-parts. This entails that the products have different amounts of process steps involved. In other words, the most complex products require more steps, which is illustrated by the dots in Figure 5 where they represent a continuous repetitive flow of part inspection and production steps up to n, which represents a variable natural number.

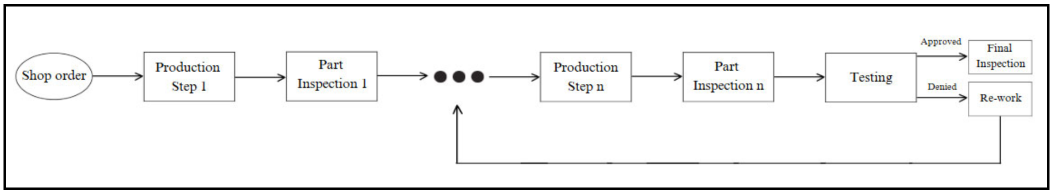

Figure 5: Presenting the workflow of Product A, B, and C which is produced in production line A

The first step of the manufacturing process as seen in Figure 5 is production which refers to the workstation where the products are being assembled and continuously produced. Each product is described through thorough instructions that are easy to follow and entail that all assembly personnel are capable of manufacturing all product variants. There are four workstations linked to production where each product takes approximately 7,5h to assemble. All the different production steps are occurring at the same workstations. However, the time required depends on the state of the products and whether they pass the part inspection or not. As mentioned, all products are very complex and require a high degree of precision to perform as desired, where the smallest errors can disrupt the performance. Due to all products being produced on the same workstation and utilising the same equipment, there are very short set-up times which are therefore considered negligible for this report. Today, the production line produces single batch sizes due to time restrictions towards customers, but they have started experimenting with batch sizes of three products. This would enable quicker production due to the learning curve, and reduce more of the set-up times. Apart from the changing process, which will require preparations and extra work.

The second step is the inspection, which refers to a physical qualitative control, ensuring a well-assembled hardware. Within this step, scratches and defect marks are searched for and a control whether the product is correctly assembled. The inspection consists of both part inspection steps and a final inspection. Both of them are similar, but the part inspection steps only focus on a specific part of the product which was assembled in the step before, while the final inspection considers the product as its whole. The final inspection also addresses more documentation handling, such as revisiting and checking Non Conformance Reports (NCR), if they are closed and settled. The number of part inspections depends on the complexity of the product. Product C contains more sub-parts compared to A and B and therefore requires more production and part inspection steps. Within production line A there are 2 seats dedicated to inspection of product A, B, and C. Generally, it takes between 45 minutes to 3 hours to conduct all inspections for the mentioned products and all inspection steps are performed at those stations.

After all part inspections are completed, the products go through a testing process. The testing involves running the software, ensuring it manages the customer requirement specification. The products get denied frequently as the requirements to pass the testing are very high and the margins are very small. This could be, due to deviations. However, in a few special cases, it is allowed to ignore those small deviations if accepted by the engineering department. If the product is approved it is sent to final inspection. However, if not, a troubleshot process is initiated. When the error is found, the product is transferred back to the corresponding production activity where it is disassembled and the error is revised. Depending on the type of error the troubleshooting will take a different amount of time. Sometimes the errors can be difficult to locate, the exact time also depends on the testing personnel's familiarity of the products.

4.7.2 Production line B

The products in production line B differ significantly from production line A where all observed products had many similar attributes and production steps. In line B, the three inspected products, being D, E, and F, differ when it comes to production steps, required material, and complexity. However, regarding the planning processes, the production lines are similar, the production planner is the one responsible for bringing the material from storage to the production line. The layout of Line B was observed in collaboration with a line manager responsible for product D, which means the analysis is more detailed for product D, while products E and F were not examined to the same extent. As the products have such a large variety in production, a similar workflow as for line A can not be as easily visualised in line B, but the three different production steps are still the same. The layout has however been mapped and visualised in Figure 6 with changes done to keep the data confidential.

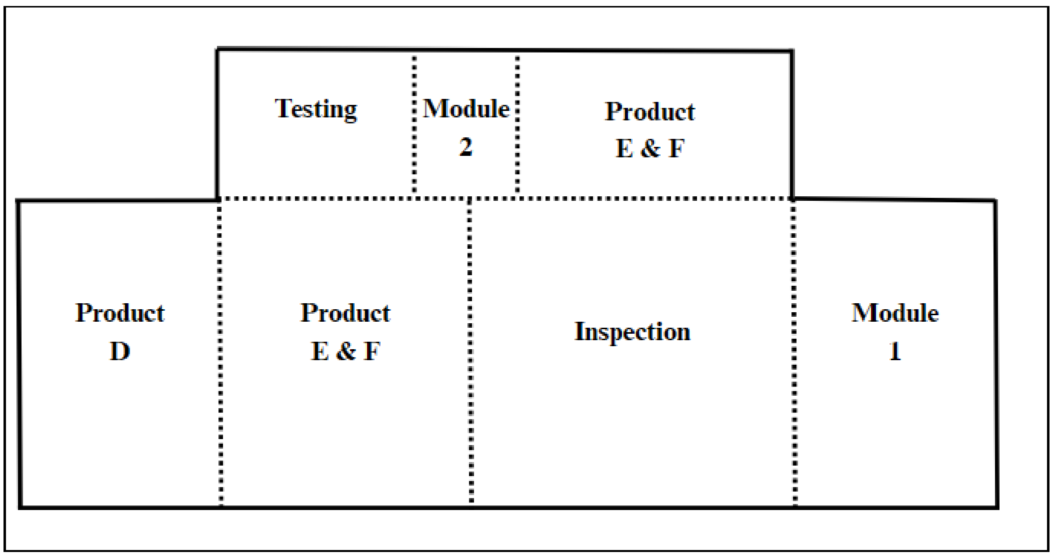

Figure 6: Production layout for product D, E, and F, at production line B

The letters in the figure show where the different products are produced. As the products in line B are heavy and bulky, the products are mostly stationary and limited to their respective area. A lot of modules and some completed products must, however, be sent to both the inspection and testing areas. The inspection area was identified as the current bottleneck since the queue is long, although its impact on project timelines remains unclear. It was however, mentioned that testing also can be a bottleneck in certain scenarios but no production step or area has shown to be a continuous constraint. The module 1 area is the furthest to the right, where some purchased modules are modified to fit the respective product specifications.

Regarding the storage of production material or modules as SS, such a setup is not feasible due to the high variability in materials used across products. Furthermore, the products themselves utilise a wide range of unique components and do not reuse similar material throughout the production process such as bolts. The large and heavy nature of the products also renders SS impractical. This does entail that waiting for some material from the storage is guaranteed, but the idle time is mostly negated as the operators can continue with other steps in the production process. There is however, a smaller cold storage to store substances within the module 2 area where since the specific amounts used for each step in production can not exactly be measured.

The complexity of individual production steps varies significantly, not only in terms of technical knowledge but also in terms of size and weight. Some steps require placing the product into a heavy frame that demands specific handling and specialised equipment such as heavy-duty tables. Other steps are much more complex and require more expertise. With that said, there are different templates the operators can follow to produce the products but the templates have different requirements in different steps where a operator with more expertise is required for some. Product D for instance, has five different variations, all of which utilise nearly identical materials. However, the configuration and placement of these materials in the product differ across each variant, resulting in variations in assembly procedures and complexity.

5. Case analysis

This chapter will address the different areas of problems which have been identified from the conducted interviews. They are presented and analysed from all different planning roles perspectives where in some cases the roles are aligned with each other's thoughts and others not. Table 9 below describes the identified problem areas, the cause(s) of the problems but also their impact on the organisation, to strengthen the authenticity, the most relevant quotes from the interviewees have been cited. Additional quotes that are cited can be found as an attachment to the study.

Table 9: Presenting the different areas of problem, with the respective cause, impact, and quotes.

Area	**Cause**	**Impact**	**Examples of quotes**
Rescheduling	- Planning against infinite resources, the MRP system suggests a planned production start date based on delivery dates and lead times without considering capacity constraints. - The material does not arrive in time - Material quality issues from suppliers and internally - To narrow requirements on tolerances	- Delays production - Increases lead times - Complicates planning work	“There is a lot of rescheduling … many products can not start in the planned time”- Product planner B “ 95 percent of the occasions where a product can not start in time is due to material shortage” - Product planner B “We reschedule every single day … through using the function run availability check in the [MRP system]” - Product planner A
Capacity constraints	- Company Alpha has a very high order intake - Capacity calculation does not consider all constraints. - Orders are not completely reserved in time.	- Schedules production to overcapacity, delayed processes - Rescheduling - Inaccurate priority - Backlog **(Line A)** - Starvation **(Line B)**	“We plan against an infinite resource” - Product planner A, Project planner 2, Project planner 3 “Not all operators can handle all the products at [Production site 2]” - Product planner B
Cross-functionality	- Located in different buildings - Members of the project are seated differently - Rush orders & prioritisation - Different interests	- Double messages - Creates conflicts	“ It is a bit complicated, generally the cooperation is good, it is a good working environment and everyone wants to do the right thing, however there is interest conflicts where we have different alignments and wants different things” - Project planner 3 “higher up, it feels like they are heavily pressured, and have to take shortcuts which they do not know the consequences of not following the process” Production planner A
Time fences	- Lack of time fences usage	- Difficulties in planning - Rescheduling - Longer lead times	“I move shop orders which has the status, planned, released, and completely reserved to prevent them from existing in the past” - Product planner A

			"If I move completely reserved shop orders, then I will have to inform higher planning levels and that is pretty much all I do, to inform, move, and reschedule…" - Product planner A
Material issues	- Poor delivery precision - Quality issues from suppliers and internally, lack of time	- Material shortage - Rescheduling - Rework - Capacity issues	" Having more material is the biggest issue … and to have the right material available. We have to little material available but the storage is overloaded" - Product planner A "A lot of the purchased goods are not arriving in time or spend too much time in the arrival storage before they get inspected and at the moment a lot of goods are shipped back to the supplier". - Product Planner B
Safety stock	- Lack of effective MRP system, indicating where the material is located - Where to allocate SS cost	- Material shortage	" It's difficult to make use of a safety stock as the cost of the material needs to connected to a certain customer order which no one want to take the cost for" - Project planner 2 "Even if there is a cost connected to buying the materials earlier, the cost for not being able to deliver in time is significantly higher." - Project planner 3
Standardisation	- Complex immature projects are constantly changed, complicates the introduction of a standard which can be widely used - Unaligned working processes	- Communication difficulties - Prioritisation issues	"There is a template and a clear standard, a project model that everyone should follow. Includes what a project contains and how it should be reported" - Sub-project leader 2 "The planning methodology is possible to follow for product planners that have mature products" - Project planner 3
MTO/MTS	- Material shortages, which lead to the usage of "wrong" production strategy	- Storing semi-finished goods in already occupied areas - Occupying operators, ineffective prioritisation - Longer lead times	" In some cases, we produce against storage, at the moment we are experiencing problems in receiving fully reserved orders and then we have to start other orders in advance that are planned for the future but where the material is available". Production planner B
JIT	- Active concept, but not used due to too much delays	- Material shortage	"There is always planned air between moments" - Product planner 1
Lot size	- Lot for lot, due to JIT, to small batches due to the lead times from procurement	- Material shortage	

5.1 Capacity constraints

A continuous theme throughout the interviews is that the planned capacity does not align with the actual production capacity, which leads to delays and planning difficulties. Several respondents highlight that the planning is conducted against an infinite resource meaning the MRP system does not fully consider the capacity aspect. Product planner A says *"We plan against an infinite resource"* which is a shared perception by all planning roles across the organisation. This leads to the case of orders stacking upon each other without ensuring enough capacity is available within the production lines. The positive aspect with this is that all orders requested from customers can be accepted but still managed to be delivered in time. However, the downside is that it creates a stressful working environment where conflicts regarding prioritisation continuously arise between the planning roles.

One critical issue is how the capacity is calculated and reflected in the MRP system. It is assumed that all employees within the production lines are able to perform all activities required to complete all kinds of orders. However, as it is more difficult to produce bigger and more complex products, it takes time to learn all activities, which generates a false picture regarding the available capacity. Therefore the planning conducted by the production planner becomes more difficult and further delays often occur as a result of this. Product planner B states that *"Not all operators can handle all the products at [Production line B]"*.
This is strengthened by production planner A who highlights the lack of expertise in handling very old products where the instructions are not as clear and developed as more recent products. This entails that even if workstations are available, the lack of competence within the specific production area can prevent the work to be performed as planned.

However, the main problem is not how capacity is measured, it is that the planned capacity exceeds the maximum capacity the production lines can obtain. This may originate from the high order intake and it is hard to foresee the available capacity for the future production. According to production planner A *"The quality is very low, there is a lot that goes wrong ... especially that things do not pass inspection"* which showcases that orders often require more time then what is planned for. When planning orders, the lead times reflected in the MRP system considers that the product is mature and calculated by the production engineering and is mostly based on assumptions. For immature projects there is some extra lead time added but how much is unclear, but it is clearly too little. In those cases where the product passes the testing phase, there are often no problems, however, they occur when the testing is not passed and it becomes a bottleneck. The reason for this can be poor quality from suppliers but also internal problems with new employees working in a stressful environment, with little learning. Another reason could be errors or to narrow margins created within the engineering department. The failed testing phase and narrow time intervals do not allow enough time to be productive and prevent future failures. *"We do not have the time to analyse the errors and can not figure out the root cause so then we experience them again"* - Production planner A.

However, there are other smaller constraints at line B which creates further problems. Due to the dynamic environment and tight schedules, a lot of orders are forced to start as partly reserved where not all material is available, instead of waiting to get fully reserved. This generates issues with the visual capacity *"The orders that are fully reserved and can start are not always up to the production capacity line"* - Product planner B. This entails that even if the MRP system indicates that an order is ready for production, lack of resources can prevent the order from being produced according to plan. The MRP system may even indicate that the planned capacity is above 100% whereas in reality it is not fully utilised. This results in production employees receiving no further work due to material shortage. Production planner B stated *"There we have a problem at [Production line B], they ask if it's possible to fully reserve orders, which is misleading".* This leads to an unbalanced workload, where line A is always experiencing too much work while line B might in some rare cases experience a lack of work tasks where some employees are starved. However, both are perceived as over planned with regards to the capacity.

From the previous paragraphs above, it can be seen that there are two reasons why employees within the production line B might not receive any work even if they have piled up orders. One is the lack of experience and one is the partly reserved orders that do not have material available. However, this is only the case at production line B, as within production line A, the issue of partly reserved orders does not have the same impact due to them constantly having a backlog. Furthermore, this generates bigger problems at production site B since the production planner does not want the output to stop and therefore finds smaller future orders to start produce and prevent a resting production. This leads to three further issues. The first is that it takes up materials which could have been used for example rush orders or other orders which are close to being completely reserved, delaying them further. The second issue is regarding the storage capacity. Since a JIT strategy is used and there is limited storage space available, smaller orders take up valuable space. The third issue is as the production employees are occupied with these small orders, they are unable to resume to the planned schedule in time. However, as previously stated this is not as relevant for production line A since they always have a backlog to catch up on instead of starting new small orders in between.

Problems created at the production lines are reflected further down the production chain and results in an escalated bullwhip effect. Project planner 3 describes the situation at the final assembly and the earlier production lines as following *"At the [Final assembly] which I work against there we do not have any difficulties with resources, but at [Production line A] and all sub assembly lines with smaller products which are required in order to build the [Final product] it is in those lines that the issues occur."*. Showcasing that even if some parts of the production is functioning well, bottlenecks at earlier lines affects the whole chains and the delivery to customers. The main problems are described to be occurring at production line A where the backlog is long and products are not being produced at a high enough pace.

From this the conclusion can be drawn that the project level is not as problematic as the product level. However, the project planners are affected by the capacity issues at the production lines connected to the product level since they are in need of those products in order to deliver the final customer order. This entails that the project planner does consider the capacity less and more focuses on the customer needs and the delivery precision through using the lead times. Lastly the Sub-project leader 2 states that *"Generally there are a lot of question marks connected to the lead times in the system, how well updated are they, do they reflect the situation today and the flow* *today, do they account for all operations etc"*. However, this is beyond the scope of this research and will not be addressed further.

5.2 Rescheduling

Another area of problem is related to rescheduling which is a continuous challenge within production planning where material availability and system constraints create daily obstacles. Product planner A describes their frequent use of rescheduling *"We reschedule every single day … through using the function run availability check in the MRP system."*. This indicates the increased difficulty in following the created production plans. One cause of this might be that if the production can not start when planned, the MRP system provides a new suggested schedule for the production to start as early as possible when materials are available. However it does not consider capacity constraints nor production obstacles, meaning the wrong date can be suggested since production can not actually start. This in turn forces frequent rescheduling which is strengthened by product planner B by the quote *"There is a lot of rescheduling … many products can not start in the planned time"*.

An additional cause of these delays is due to material unavailability, both in terms of bad quality but also delivery precision where the material does not arrive in time or spending too much time in arrival control. This is highlighted by production planner B who states *"95 percent of the occasions where a product can not start in time is due to material shortage."*. Depending on product characteristics, the consequences vary, *"[Product X] does not require as much rescheduling compared to more complex part products.*" - product planner A. However, when procured material does not arrive in time and the quality control requires more time then planned for, the schedule needs to be adjusted which in turn generates delays further throughout the whole production chain. Another challenge is that different production lines are interdependent, meaning if the earlier line is not producing according to schedule, it will affect the others negatively. Additionally, each reschedule results in a movement of required capacity and amplifies the capacity problem further.

What is described above affects the production lines differently, where line B is more affected. To handle the rescheduling created by material shortage production planner B would prefer longer strict planning intervals to manage. This would entail that the shop orders are less allowed to change within those more strict intervals which results in a lighter planning work ahead of production start. Meaning that the production planner can match the available workforce and their level of knowledge with the respective tasks. However, within production line A this would not have as great an impact due to the large backlog and overflow of work. "There is always more work than we can handle" - Production planner A, showcasing the overcapacity. Even if longer strict planning intervals were to be implemented they would still not be able to plan as far ahead as the backlog must be considered first. However, it would still be useful in the future when the backlog is reduced.

However, the situation is different in comparison to a project planner since they are driven by a customer order which creates clearer deadlines which results in great costs when changing the deadline. Project planner 2 stated that *"The project does not reschedule until a command order from management is received"* which is in line with project planner 3. This is the biggest difference since product plans are very fluid while the project in general can not be rescheduled as easily. Another difference between the two roles are that product planners focus more on the production constraints and the operative challenges while a project planner focuses on the end delivery to customer to a wider extent bypassing the constraints. The reason project planners are not as affected by delays within the products is because the final assembly process can start without having all products available on time. Some products can arrive later on in the assembly process as they are not required early on.

5.2.1 Material issues

Another identified area of problem is regarding the material issues, both in terms of delivery precision but also quality issues. Product Planner A highlighted the imbalance between stock levels and availability "*Having more material is the biggest issue … and to have the right material available. We have too little material available, but the storage is overloaded.*" Late deliveries and delays in inspection further disrupt production, as Product planner B pointed out delays in inspection and supplier returns *"A lot of the purchased goods are not arriving in time or spend too much time in the arrival storage before they get inspected, and at the moment, a lot of goods are shipped back to the supplier"*. These inefficiencies result in delayed production, increased lead times, and overcapacity.

From the interviews conducted, several potential reasons regarding the quality issue have been highlighted. The first reason being that there is a high degree of complexity in each product and there are very few products bought per occasion, which reduces the bargaining power towards suppliers. This means that other companies get prioritised who is a more important customer. Another potential reason heavily connected to the first one is therefore that the company receives bad quality products already from their suppliers. This means that they do not pass the quality assurance at arrival to the warehouse, causing further delays and rescheduling problems. Additionally, poor arrival storage handling internally might be another reason. This since the workload is over the capacity limit, resulting in careless handling which can lead to products of poor quality passing through or being damaged. The same argument can be said within the production lines, where they are scheduled to work at over capacity in a stressful environment with complex products. Finally, the requirements on the products passing through inspection are too high meaning that functioning products are not accepted due to tolerance deviations. The product can be within the tolerance meaning the quality is not an issue but it still does not get accepted and the error search will result in dead-end solutions.

The reasons for poor delivery precision has not been explicitly mentioned nor explored, although throughout the interviews, different thoughts and speculations have been discussed. The first reason refers to the internal operations where the narrow time schedules on immature projects have led to stressful working processes and shortcuts resulting in poor delivery precision. Engineering documents might have been too diffuse or unclear leading to frequent changes which have not been reflected to the suppliers, constantly creating new material requirements and changes within the product. Additionally, as previously mentioned, it has been stated that the time interval towards procurement has been increased from approximately 2-4 weeks depending on the project complexity. This indicates that the time towards procurement has been too short and it is unclear whether 4 weeks is enough. Lastly, the obvious alternative that the supplier has not delivered according to the agreed time is also a reason.

5.2.2 Time fences

The concept of time fences is related to the rescheduling problem as from the interviews the identification of an insufficient use has been made. *"I move shop orders which have the status, planned, released, and completely reserved to prevent them from existing in the past"* - Product Planner A. From the quote it can be seen that no matter what status the orders have received they can still get rescheduled by the product planner which in theory should be impossible. However, there is a divided perception of to what degree it is used or not. Product planner B argues that it is used to some extent in mature projects since the guidelines are more standardised and that the problem occurs at immature projects. On the contrary of production line A where all kinds of shop orders are constantly rescheduled regardless of project maturity status.

In regards to procurement, project planner 3 argues that time fences exist and are considered in every purchase requisition and throughout the chain *"I have to release the purchase requisition in time for procurement to have enough time to work against the supplier"* - Project planner 3. The time fences exist in the form of a set time interval when the purchase requisition needs to be delivered to the procurement department in order for them to have enough time to bargain for a good price and ensure an in time delivery. Within this time fence it is not allowed to change anything within the purchase order, neither the time nor amount. According to project planner 3, the usage has increased by time where the PR previously had a deadline of 2 weeks but now extended to 4 as the importance of it has been recognised. The same argument is applicable towards production where shop orders need to be completely reserved before the production can start. However, as previously discussed this does not fully work.

5.2.3 Safety stock

Generally, SS or safety time is not commonly used in the organisation partly since JIT is an adopted concept to keep costs low and the storage areas are limited. However, there are some exceptions where the need of a SS has been identified. Product planner A has described the new implementation of a small SS of a certain purchased module which is the most critical one and often results in defects and a delayed production. Additionally, at production line B, there is a SS on consumable goods in production such as screws and oil as its usage is hard to measure due to spillage. This is also mentioned by the project planners and used at the top level as well.

Product planner B has also expressed the inaccurate stock calculation used by the existing MRP system, *"The safety stock is calculated for what is available at the house in total and not just what is available at a specific storage, it counts what is being used at the production lines and at [Site 2]"*. Meaning that the system provides an inaccurate reflection of the real scenario. The material might be empty at your location but the system will not release a purchase warning. Furthermore, the MRP system presents the need for procurement of material only when the warehouse stock has been emptied and shows a zero, which has been expressed as very problematic. This has also been highlighted by the project planner 3 who attempts to send PR's before the stock runs out to avoid running out completely. This is also a common strategy used by all planning roles, but the effectiveness is varying.

One of the main reasons for not using a SS is the lack of available space to store material, *"... we have too little material available but the storage is overloaded"* - Product planner A. Another reason is that all costs need to be allocated to a customer order, *"It's difficult to make use of a safety stock as the cost of the material needs to be connected to a certain customer order which no one wants to take the cost for"* - Project planner 2. Since each project works and is measured individually, conflicts regarding which person should allocate the cost to their project and in turn the end customer arise since no end-customer wants to pay for non-value adding activities. However, the need for a SS has been highlighted by project planner 3 *"Even if there is a cost connected to buying the materials earlier, the cost for not being able to deliver in time is significantly higher."*.

The consequences of not using a SS have been discussed as increased rescheduling which in turn prolongs the lead times due to the appearance of a cascade effect throughout the production. This results in an overall increased cost for the organisation that the customer in the end has to pay for. Although, as previously mentioned it is difficult to know whether the SS would result in a higher or lower cost compared to delivering late or the cost connected to rescheduling and longer lead times.

5.3 Cross functionality

Another area of problem identified is the cross functionality and how departments and roles communicate to ensure a well working project. A recurring opinion is that the need for better communication and collaboration between the roles in order to handle conflicts is frequently mentioned throughout the interviews. However, the situation has improved over the last years, mainly within the projects. One reason for this can be the implementation of weekly meetings where the project planner receives a better understanding of the product and production planners' situation. This can be seen from the following citation*"In the later years the collaboration has been much better"* - Product planner A.

Even though the collaboration has increased, one of the main identified problems is the collaboration towards the procurement department where the issue lies in the physical distance. A continuous problem is that the roles in responsibilities towards procurement are not clear. The sub-project leader 2 indicates that a lot of planning roles are connected to the same buyer regarding the same project, meaning that the information gets twisted and received differently. This creates an unclear description of who should make the different decision. This originates from the physical distance between the departments *"Production and procurement got separated last year, so there a lot falls between the chairs, not clear who works with whom"* -Sub-project leader 2. Furthermore, decisions often need many approvals which aggravates and delays the process. This further is strengthened by project planner 2 which perceives that the sepations towards procurement creates greater losses of information and aggravates the collaboration. Previously the day to day communication was easier to initiate, now *"You often get stuck in the mail conversations if you disagree instead of just talking"* - Project planner 2.

Some planners experience that the communication still needs to improve between the different planning roles within the projects as well. Product planner A experiences the different planning departments as separated which make the informal information exchange difficult. *"The projects are seated for themselves and the same with products, but it might be better to communicate more on a daily basis to receive the informal information exchange … then the formal information will be transferred more naturally"*. However Product planner B contradicts this statement and argues that the physical distance is not a problem and the informal information exchange is favorable as it is today. Therefore the conclusion can be drawn that there is a big difference between the projects. Here the arguments for staying in the activity based workplace is that each product planner belongs to multiple projects simultaneously which would complicate the project based seating. Further arguments are presented to be that when problems within the rolls occur of how to handle the work tasks it is beneficial to be seated with colleagues from the same role. In this case it is possible to receive help quickly and share learnings and information by utilising the economics of learning.

Project planner 3 illuminates that even if everyone wants to achieve the same goal, conflicts arise when the interests from the different roles collide. The production planner aims to create a well functioning production schedule while the project planner is more focused on delivering the project in time to the customer. This is described by the quote *"It is a bit complicated, generally the cooperation is good, it is a good working environment and everyone wants to do the right thing, however there are conflicts of interest conflicts where we have different alignments and want different things"*. - Project planner 3. Another aspect is regarding priorities between projects that need the same resources. Both in terms of mature projects where the discussion regards which project should receive the produced products. While in the immature projects the sub-project leader 2 mentions that the difficulties lies within how to prioritise what project should be produced first. Today a combination of FIFO and whoever shouts the loudest is used but that might not be the most optimal solution. This creates friction within the relationship between the production planner and project planner. In the immature projects the production planner A states that *"higher up, it feels like they are heavily pressured, and have to take shortcuts which they do not know the consequences of not following the process"*.

Project planner 3 describes a similar challenge where product planners want to follow the planning methodology strictly while the project planners have to bypass them to deliver the project in time. Meaning the same problem is mentioned by all roles but they see it from different perspectives. Not so surprisingly the relationship between a production planner and a product planner is more well functioning since they follow the same methodology and work within mature projects. In the extent that it is possible a wish from the production planners is that all information travels through the product planners to avoid confusion since the product planners follow a well functioning methodology. However, this might only work in mature projects since the project planner is responsible and the owner of the products in the immature ones. Also adding to the complexity is that project planners can in some cases take shortcuts to be able to deliver in time which is perceived as stressful by the production planners.

5.3.1 Standardisation

There is an established planning methodology which acts as a standard way of working for all different project levels. The production planners found the planning methodology to be very useful as it streamlines the communication and ensures that all information is correctly delivered between the roles. This since they have been a part of the development group. The product planners also prefer this way of working and have been taught by the production planners how to use it. This has made their work and communication easier and more effective but also reduces rework. However, the project planners are not equally convinced, *"The planning methodology is possible to follow for product planners that have mature products"* - Project planner 3. They share a common view, that the planning methodology is good for product planners but too strict and non adaptable to dynamic environments and does therefore not work well with immature projects and rush orders." *Within the projects we focus on the customer and to deliver and we have to solve the problems and find ways to deliver which means that we need to make use of shortcuts*." Project Planner 3. From this it can be seen that the product planner focuses on delivering well prepared orders towards the production planners while the project has the customer in focus instead. Therefore the product planner can be squeezed in the middle since they want to deliver to the project but also deliver reasonable production schedules to the production planner. All roles share the same interpretation within this area.

With that said, the sub-project leader 2 highlights that there still is a set standard for project planners and sub-project leaders *"There is a template and a clear standard, a project model that everyone should follow. Includes what a project contains and how it should be reported"*. Although, as earlier mentioned, the project planners express the need for adaptation depending on the project and its priority. *"Many departments and roles have few working ways, you have few or only one way or working which you apply on everything, one process, 1 method, and that is a problem to me*" - sub-project leader 2. From this quote, the sub-project leader 2 goes against his initial statement and aligns with the project planners as too much standardisation can become a problem in a dynamic environment. Project planners must do whatever is required to deliver in time and can not follow strict procedures at all times.

5.4 Additional considerations

During the interviews, several other experienced problems have been brought up, those being regarding the production strategy, JIT concept, and the current lot sizes. These mentioned problems will be addressed and suggestions on improvements will be proposed by the usage of case studies in similar scenarios later on in the discussion. The current production system used in the whole organisation at every production unit is MTO which was fully functional when the organisation was not planned to over capacity and received fewer orders. However, due to the increased demand, this strategy is not viable as lead times are very long when not planning in advance. This has led to several material shortages as each order is produced individually without considering the whole picture. The material shortage is heavily connected to the misuse of the JIT concept. It is a coined concept which should be used throughout the whole organisation but due to the shortages and experience many interviewees have departed from it to better be able to produce. With that said, the JIT concept can be considered as a root cause for several of the other experienced problems that have been addressed during the interviews which have been mentioned in the previous chapters. The usage of lot sizes described by the different planners is that the PO sent to procurement is either calculated by using a lot-for-lot strategy or by batching orders by date together.

6. Discussion

This chapter will discuss the three different stages of transition. The first is what can be done before the main transition from a project-based to a product-based way of planning takes place in order to achieve a good result. It will address what problems can be prioritised according to the “low hanging fruit matrix,” and also based on the data that has been gathered. Second, it will discuss how to perform the transition based on previous studies and how it should be done in the present case company. Thirdly, a discussion on what potential impacts this transition could have on the previously addressed areas of problems will be held.

6.1 Pre-transition

Before the transition can be conducted, it is important to be prepared and ensure that potential obstacles are removed to prevent them from aggravating the process of transitioning (Kliem & Ludin, 2019). From the analysis, several problems have been identified, where some are beneficial to address before the transition and others later. Another important aspect of the transition is to have sufficient support from management when performing changes of a larger size, since changes can create a feeling of lost control and make employees unsure, creating resistance (Hwang et al., 2016). The Hwang et al study emphasizes the importance of high quality relationships with management to avoid resistance, while this report also suggests using quick wins, providing clear positive results to lower the resistance. This is then leading up to the usage of the above mentioned “Low hanging fruit matrix”.

It identifies which problems are relatively easy to solve, requiring few resources, but still gives a noticeable positive result. This suggests that it can be good to start with the low hanging fruits (Figure 9), those being implementing a SS and establishing a better capacity measurement. Another benefit of prioritising the company's capacity allocations with respect to quick wins is that it also brings positive outcomes to employees. This is because it can enhance the employees' motivation when seeing quick results (Hubbart, J. A. 2022), which will be useful in taking on the bigger transition towards a product-based way of working. Also, as described, some problems outside of the low hanging fruit box, identified by the authors based on the data, are beneficial to improve before the transition in order to see the full results of it. This is since they will not be improved by the transition itself, and instead rather hinder it.

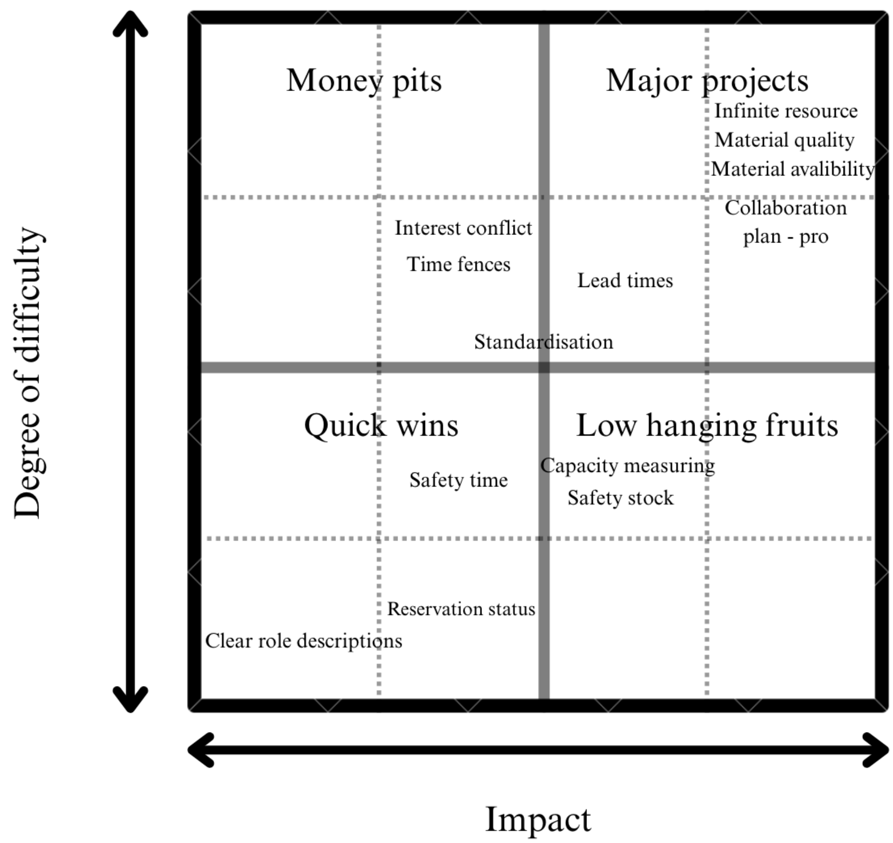

Figure 9: Low hanging fruit matrix, showcases how difficult it is to improve the identified problems and how large the impact would be

6.1.1 Low hanging fruits and Quick wins

Based on the low hanging fruit matrix, three quick wins and two low hanging fruit problems are suggested to be addressed before the main implementation to hinder aggregating problems (Kliem & Ludin, 2019). However, all problems in the lower half of the matrix are not required to be completely addressed and improved before conducting the transition. Each project requires time which is of value and since the main effect of those quick wins is to boost the motivation (Hubbart, J. A. 2022), it might be enough to do one or two at this early stage. *The first problem is* regarding the safety time. Safety time is considered and utilised in a few areas across the organisation with one of those being the PR process to procurement. There is a function in the MRP system that allows the planners to add a customised safety time which is decided individually. This function is however not utilised fully and could potentially result in streamlining the production planning.

Regarding this case, there are difficulties related to utilising safety time, such as the limited storage that is available at the warehouse. Therefore only few products which has shown to be problematic regarding availability are recommended to use this. Additionally, if too many uses it, it will cause increased capacity at goods reception which is already at a high capacity, resulting in an increase in delays and the risk of competing out more important material that needs to be prioritised. However, for other cases it could be much more utilised.If the implementation to utilise safety time does succeed, potential results would be a smaller decrease in project delays and rescheduling along with slight decreases in lead times.

The second problem is similar and concerns the lack of SS. Although SS is not very difficult to implement, it comes with challenges related to space allocation and cost distribution. At the case company, SS is constrained by limited storage capacity, necessitating prioritisation of materials based on multiple factors of which some could be criticality, cost, volume, and time sensitivity. High-value material and components, in particular, are a difficult challenge since allocating SS for them often requires rationalising a significant additional cost. As no sub-project manager wants to allocate this cost towards their project, it often ends in buying just the required amount to finish each individual project. Therefore, SS should be carefully planned to make sure it provides value without causing extra costs or taking up excessive space. On the other hand, the cost related to shortages is usually very high, therefore, the cost of SS should be considered as it could ultimately reduce the total costs (van Kampen et al., 2010).

Thirdly, the reservation status can easily be overlooked and improved with few resources. Again, seeing quick results which will boost the motivation within the teams (Hubbart, J. A. 2022). The reservation status itself is regarding what formal status the shop orders which are planned have received. When an order is scheduled to start all required materials need to be available at the production facility and the order needs to receive the status completely reserved to start. However, today when an order is planned for it can occur that the status is only partly reserved meaning the order will not start being produced. The root cause of this is the material issues but this will be further addressed later. Therefore the degree of difficulty to change the status in the system is not specifically complicated. This would also mean that it would prevent so that products which are not ready also not reserves all material too early since it hinders other projects from receiving them. If orders only are completely reserved when needed enough material might be able for other orders which can not be completely reserved. The effect would be that more planned orders can start on time which also would make the production planning easier to match the projects with the right production personnel. This would increase the yellow line in Figure 13, meaning more products would be produced in total at line B, and right personnel would be available when needed to a broader extent.

Lastly, the capacity measuring is also beneficial to consider before conducting the transition. Implementing a way of measuring the capacity is believed to be relatively easy. Akhundov & Rustamov, (2024) argues that a fully capacity utilised production along with an understanding of the capacity limits, would lower the costs and idle time for the firm. However, in our case if a capacity measurement of some sort gets established, it would also become easier for production planners to plan the right operator towards the right product due to a more stable schedule. This inturn is a large identified problem. This could result in a much more efficient management of experienced operators which is especially important in production line B where some stand empty handed.

Based on discussions with a company employee with long experience and thus expertise it is suggested to classifying each product into its respective “difficulty” category. It does however become a problem when evaluating the different operators on their area of expertise and knowledge and managing this data for a longer period of time. It is difficult to foresee future operator expertise as conditions may fluctuate greatly, the turnover rate of operators vary and their willingness to learn is unknown. Depending on the degree of implementation, the difficulty and potential impact increases, thus a suitable starting position is evaluated within the low hanging fruits box. Seen from Qarahasanlou et al., (2022) it could be beneficial to measure the throughput capacity to see what volumes each machine/station can provide and present it in net capacity, to not include capacity which can not be utilised for production. Further to also assess both machine-hours and man-hours since the complexity of products are high.

Additionally, standardisation is another area of problem which could be considered as a low hanging fruit depending on the situation. Therefore it is addressed within the pre implementation phase. Standardisation is difficult to evaluate as both the implementation difficulty and impact varies significantly between the existing project structures. In the mature project structure, where products and ways of working are established to a higher degree, standardisation regarding the production planning is much easier to implement. Product- and production planners have their set methodology about what needs to be done and how to do it. Similar methodology can be implemented towards the project planner but also to some degree towards the sub-project manager. This could reduce the potential miscommunications and misunderstandings (Goel et al. 2023) as a set and defined way of working throughout the entire project would be established. With that said, mature projects are still dynamic to some degree which makes it more difficult for the higher levels of planning to have a restricted way of working. Therefore, together with related functions, a framework where the project planners and sub-project managers could try to work towards could still be implemented. This implementation could significantly increase the efficiency throughout the planning processes and levels (Jonsson & Mattsson 2009). Thus, a standardisation of the mature project structure is evaluated to not be a too difficult implementation process while still providing a large positive impact towards the organisation.

In converse, the immature project structure is much more dynamic on all levels and not much is established. Therefore, implementing a framework for this project structure would not only be very difficult to implement but also unsustainable because of the high variation in project specifications and dynamic environment. Consequently, standardisation of the immature project structure is evaluated to be very difficult to implement while not having a large impact as it would be unsustainable to maintain. An important note is however as both project structures have the same planners and production lines, implementing a standardisation on one structure could be difficult. This since projects from different structures could potentially collide, disrupting the standardised workflow from mature projects.

Tabel 10: Presenting the quick wins and the low hanging fruits and how they should be implemented/improved

Area of problem	Implementation/Improvement
Low hanging fruits and quick wins	
• Safety time	1. Start using and updating the safety time function in the MRP system 2. Only on critical components, due to inadequate storage space
• Safety stock	1. Release larger POs for certain products based on factors, to avoid storage constraints. 2. Avoid expensive products to simplify the cost allocation
• Reservation status	1. Update the reservation status in the MRP system 2. Avoid stating "completely reserved" before actually required
• Capacity measurement	1. Divide products into different classes based on required capacity/difficulties 2. Evaluate and regularly update operators level of experience, to receive right products 3. Measure the throughput capacity, on machines and workforce 4. Avoid to long time horison due to increased difficulty in foreseeing the exact supply of capacity
• Standardisation	1. Implement a more standardised way of working, providing clear instructions for project planners and sub-project leaders in mature projects

6.1.2 Cross-functionality issues

From mainly the interviews but also the observations the cross functional collaboration is suggested to be looked over beforehand to achieve full effects of the transition. As mentioned in the analysis the main issue with regards to cross functionality is the collaboration between planning and procurement, originating from poor communication due to the physical distans, which also is concerning according to Pinto, (2020). If this does not improve, the transition will not itself improve the production, since material will still arrive late and in poor quality. Pinto (2020) suggests organising buildings to encourage communication by positioning people into project formed groups which in this case is a radical change. A more simple improvement could be to continue working on improving the weekly meetings mentioned by product planner A and also include the respective buyers to it. This would improve the experienced distance, enchanting the communication. It is expressed that the weekly meetings implemented in some projects has improved the collaboration, leading towards the suggestion to strive towards implementing it as a standard across all projects. Furthermore, this issue can also be alleviated by solving another problem discussed by sub-project leader 2 regarding the lack of clear role descriptions.

Multiple people with different roles working in the same project are connected to the same buyer, aggravating the information exchange. When multiple people are connected to the same buyer the information can easily get twisted since it is perceived differently from all persons involved. The risk of different information being bypassed is also heavily increased. Pinto (2020) discusses the importance of clear role descriptions where everyone understands their own responsibilities but also their colleagues to prevent misunderstandings. This would probably mitigate the misunderstandings as fewer people would be aport of the information exchange towards procurement. As discussed by El Amrani et al. (2006), this could lower the overhead costs and reduce cycle times. Therefore, this thesis has provided a role description of each planning role in the department which can act as a ground for further work. However, extended responsibility descriptions regarding the information exchange towards procurement is needed and should be shared to all affected employees to strengthen the understanding and simplify the information exchange. Pinto (2020) also argues for strict rules and procedures since it can help assign duties and resolve conflicts. As seen in our case, conflicts of intrestes has arrise and can hopfully be mitigated by rules and procedures. Therefore more strict rules from management, stating which role is responsible for what regarding the information exchange towards procurement is beneficial. For mature projects this could also be implemented within projects by stating that the information should travel from the project planner to the product planner who forwards it to the production planner or similar. However, in immature projects the project planner is the one responsible for most of the communication and those would not benefit as much.

As slightly mentioned Pinto (2020) discusses how to lower the perceived physical proximity by placing project groups with people from different functions on the same area or at least floor. This is also addressed by product planner A which mentions that the informal information exchanges across the project is difficult to achieve since you are seated with people from the same function instead of project wise. However, others are not agreeing with this and argue that it is more beneficial to be seated as it is today to help each other. The product planners often experience the same problems and can then easily assist each other if they are seated closely together. According to Santa et al., (2023) this approach could foster the knowledge sharing which in turn leads to more innovative ideas and solutions. Also a problem regarding a change of workspace layout is that each product planner is involved in multiple projects simultaneously. Therefore, the conclusion can be drawn that a more effective way can be to improve and extend the already existing weekly meetings. Also to include people from higher positions to minimise the accessibility described by Pinto (2020). Therefore, it is beneficial to keep the workspaces as they are today, since the project groups at least are located on the same section at the same floor level.

Further problems connected to cross functionality are regarding the different interests of the different planning roles. Project planner 3 expressed that the production planner aims to create a well functioning production schedule and works closely with the product planner. While the project planner is more focused on delivering the project in time to the customer. All three roles have expressed an understanding of the dilemma the others are experiencing but have to stick to their own interest in the end to deliver according to their working tasks. According to Pinto (2020) and El Amrani et al. (2006) it is very important that everyone within the organisation understands and works towards the same superordinate goal. The purpose is to involve multiple functions into a collaboration action to fulfill the higher need. However, the tricky part is to set the superordinate goal so it does not replace the sub goals but rather connect them into a bigger meaning. Using the same goal across different roles ensures a common strive to achieve it together by looking at the team's best and utilising everyone's knowledge. Therefore the suggestion made by the authors is that this can be done by implementing common KPI:s which should be measured both across roles and within. The important aspect as Pinto mentions is to ensure the common KPI does not separate from the individual ones, but rather connect them.

Tabel 11: Presenting the different problems regarding cross functionality and how they should be improved

Area of problem	**Improvement**
Cross functionality	
• Physical distance to procurement	1. Broader weekly meetings, involving the respective buyers 2. Clear extended role descriptions, especially towards procurement
• Information towards procurement gets twisted and miss understood	1. Clear extended role descriptions, especially towards procurement 2. More strict rules towards procurement
• Information exchange within projects	1. Extended weekly meetings 2. More clear role assignemnts
• Colliding interests of different roles	1. Look over the superordinate goal 2. Implement common KPI:s measured across roles

6.2 Transition

This section discusses how the theoretical insights can be applied to transform the production strategy of the case company. The transition framework is structured around four factors that have been found appropriate from literature: segmentation of products, the determination of decoupling points, the approach to lot sizing, and the capacity allocation. Each factor is important when deciding a production strategy that aligns with the company's operational constraints and the customers' requirements.

6.2.1 Case company segmentation

The segmentation of products or product families are of great importance to decide what production strategy to apply and where to introduce the decoupling point. From previous studies multiple methods for this are presented where the segmentation is based on different factors. Perona et al., (2009) proposed a suitable method used in a very similar environment providing a good baseline for segmenting. It uses the order frequency and order volume as the two main factors but also involves the degree of customisation. However, this study was conducted in a different industry, meaning those factors are not the most suitable in this case. The industry present for this case is represented by high degree of technology, complex products, stricts quality requirements which is leading up to long lead times, meaning it does not fully reflect earlier studies.

For this thesis it is proposed to keep the order frequency as one factor but replace order volume with degree of customisation as the second of the main factors. The frequency is chosen since there is very limited storage space at the facility, meaning the turnover rate is important. If a MTS is partly implemented it would increase the amount of stored products which is not possible. A high order frequency also increases the predictability enabling the usage of a forecast which acts as the foundation for the MTS. Although, if the limited storage situation would change, which would be beneficial, this factor is not of as much importance.

The more important factor is order volume, however it is not chosen partly due to the same storage issue but also due to lowering the complexity of the method. Only having two factors enables a simple 2x2 matrix presenting clearly what production strategy should be used. As a starting point this should be enough, and can be expanded later on. Furthermore, the problem with order volume is that if there would only be one customer each year ordering a large batch, this would entail much needed storage, which is not possible at the moment. Therefore it is more important to focus on the order frequency. The degree of customisation is chosen as a main factor since the company is embossed by many customer specific solutions. Which in turn is a huge problem for MTS, excluding some product modules directly.

From theory and the case study conducted by Perona et al., (2009) it can be concluded that a MTS structure is more beneficial when the degree of customisation is low and order frequency high. In this case study it is the same and only slightly modified as previously described. This generates Figure 10 below, visualising that when the demand is stable and the product is more standardised the usage of a MTS is beneficial, and vice versa. It also showcases that there are two grey boxes representing the grey area where it is more difficult to determine the production strategy. Those boxes can benefit from using a hybrid structure, meaning the first part of the production is MTS while the later is MTO. Where this change should occur is determined by the decoupling point, which further can be decided by using other methods proposed by Jeong (2011) or Rafiei & Rabbani (2014). This is wanted since a MTS according to Jacobs et al., (2018) increases the service level, meaning that the lead times can be cut and customers are generally more happy, which also is seen in our case. However this is done at the expense of storage cost and risk of obsolescence increases, indicating that the right products need to be found.

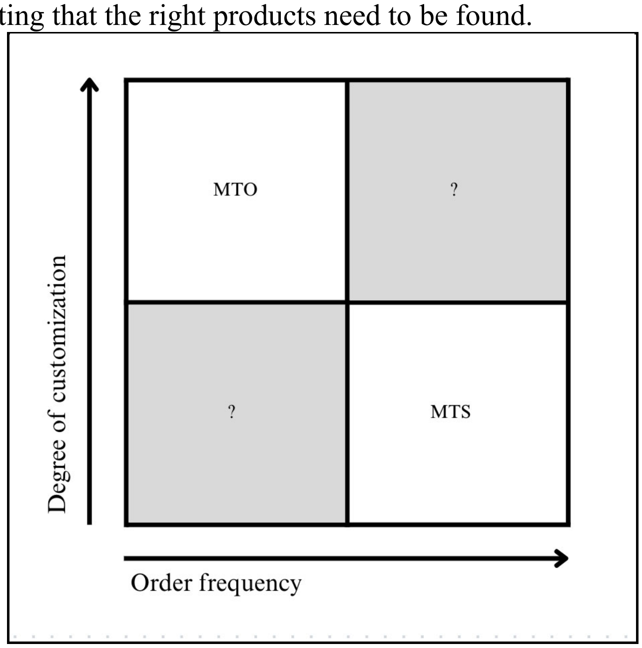

Figure 10: Visualisation of the production strategy determination model inspired from Perona et al., (2009).

Here it is possible to use either Jeongs model or Rafiei & Rabbanis model to decide if a MTS can be suitable for parts of the production. Jeong (2011) proposed the usage of a P/D ratio can be implemented, placing the production lead time and the delivery lead time in relation to each other. If the P/D ratio is less than one, meaning the delivery lead time is longer it is beneficial to use MTO and when the production lead time is longer it is beneficial to use MTS. However, it is also important to consider the demand volatility, if this is high a MTS is never favourable. Furthermore, the Rafiei & Rabbani (2014) model can also be used where five key criterias are considered. If the product "scores" high on the first four and is predictable on the last one the product is very useful to produce with MTS, otherwise the closer to a perfect score the more clear is the MTS. Those criterias are as mentioned in the theoretical frame of reference: modularity, commonality, compatibility, reusability, and demand behavior.

6.2.2 Case company decoupling point

When determining the optimal placement of the decoupling point, the case company must evaluate the trade-offs between the responsiveness to customer and the inventory related costs but also the choices influences on lead times, customisation capabilities, and inventory levels. Perona et al. (2009), highlighted that products with a more predictable demand and a lower degree of customisation, are more suited for a downstream decoupling point. In the case of company Alpha's context, production line A features a set of products that are relatively standardised and follow similar production flows and material requirements. This consistency positions line A for a downstream decoupling point, closer to the finished goods storage, aligning with a make-to-stock strategy. Thus, increasing service levels but also the inventory carrying costs (Jacobs et al., 2018). Therefore, the case company could implement a downstream decoupling point for production line A and consolidate into a forecast driven production flow, with a supported module-storage and SS for the high rate of defects and denied testing (Jonsson & Mattsson, 2009). The expected results would be a maximisation of throughput and delivery performance. An additional potential result could be an improvement of cross-functionality as the current project structure may change. This since the lower levels, being the product - and production level, will not be as connected to the project but more towards the storage. This could entail a lower risk of miscommunication and misunderstanding of other's roles.

Conversely, according to Perona et al. (2009), products with high uncertainty in demand and higher degree of customisation, where the decoupling point should be moved upstream. In the context of production line B, the products are complex and varied. An upstream decoupling point may be more suitable due to the high level of customisation and long manufacturing lead times. However, for more standardised sub-assemblies or common and shared modules, such as those found in product D's five variants, a midstream decoupling point at a shared module level, could optimise efficiency without compromising the service level. Additionally, the concept of postponement could be used as this strategy improves responsiveness. The case company could produce standard modules to stock and finalise the assembly when orders have been placed. One important note is however that since the storage is limited, it is more suitable for line A where the products are smaller. The current problem is that in order to implement this, the product can not differ in specifications too often, which is the case for most products. For the ones that are established and stay the same it is however a suitable concept.

Based on the previous literature (Perona et al., 2009; Jonsson & Mattsson, 2009; Munyaka, 2022), the case company should adopt a hybrid decoupling point strategy, applying different decoupling points across product families. Having regular cross-functional planning meetings and a dynamic review of product segmentation and forecast accuracy will be essential to continuously adapt decoupling point positions over time.

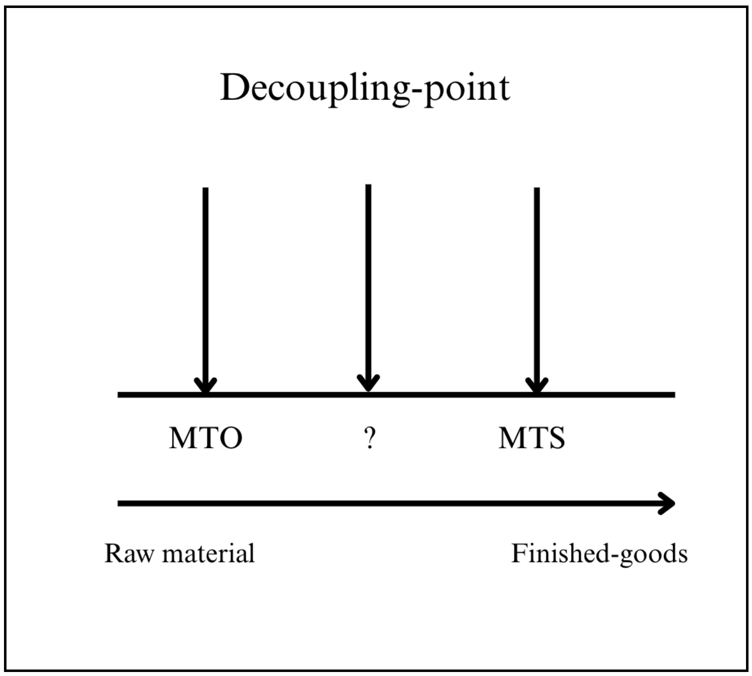

Figure 11: Presenting where in the refining process the decoupling point should be allocated

6.2.3 Case company lot size

What lot size to apply for each product family depends on the decided production system. From Figure 3 presented in the theoretical frame of reference multiple methods are available within each box. In other words, the choice of lot size is more complex than just determining the production system. However, Perona et al., (2009) suggests what box to choose from when the production system is in place. For product families which received the MTS structure it is recommended to apply one of the lot sizes which utilises a fixed order interval and a varying order quantity. What can be noticeable is that if only few customers are involved it can be useful to collaborate more closely with those who achieve an accurate ordering quantity. Otherwise lot for lot which is the current strategy, periodic order quantity or period of supply can be applicable.

As earlier mentioned the products this thesis can see a potential for being applicable here are all three products from line A and product D from line B. However, the storage space is still an issue meaning the intervals will need to be kept short to not store more than what is possible. How often the order should be made is theoretically according to Jonsson & Mattsson (2009) a weight-off between ordering cost and storage cost. In this situation the downside can be that the intervals need to be shorter than what is best seen from an economical point of view. Because MTS provides a stable schedule preventing the high ordering cost by utilising larger batches. Therefore it would be beneficial with more storage space to cover the higher batches connected to MTS. Although, it is hard to say exactly how to act since no numbers have been considered. However, what can be said is that the time needed to pick the right materials will increased due to the extended storage space. This in turn means that more picking personnel can be needed.

For products using the MTO system, nearly all viewed products should apply a strategy allowing the time to vary and the quantity to be fixed. Since those are driven by the customer order which usually occurs more rarely it is better to only order the amount required each time. This would point towards using a FOQ or EOQ. However, Perona et al. (2009), argues that a Lot for Lot also could be applicable since it orders the exact amount the customer needs. If Lot for Lot were to be applied for company Alpha, the use of a SS should also be considered to avoid shortages (Jonsson & Mattsson, 2009). Then there is also another dimension to consider, in the case of the focal company if the products ordered are of a small volume and an expensive ordering cost, such as products requiring paperwork it can be useful to instead use the EOQ. However, as this is beyond the scope of the thesis, it has not been addressed further. Munyaka (2022) states that the FOQ only is useful when the demand is predictable and stable. Usually MTO is represented by the opposite, creating a dilemma when deciding the optimal lot size for MTO products. From this it is hard to determine what lot size strategy should be applied for MTO products, it has to be deeper studied for each product family.

From another viewpoint the focal company has expressed that most of the orders today are released to procurement when required according to the MRP system. Only when it is possible and the employees are experienced do they batch purchase orders together to give procurement more bargaining power. This might work well today due to the space issues but seen from a theoretical point of view it is better to use EOQ and continue releasing more purchasing orders at a time to allow the EOQ to be followed. Since the risk today is that if the orders are not released more than once each month to cover the upcoming month the quantity might not be enough to apply EOQ. Although, this again suggests that more storage space might be needed. So the question is not easy to answer, but the limited storage space needs to be heavily considered when deciding the order quantity and interval. Therefore, in the end the production strategy itself might not be the decider for what lot size to apply. Instead the characteristics of the products such as volume, the price connected to purchasing it, and how urgent the need is should decide.

Lastly, when considering the products which are located in the grey boxes in Figure 10 representing a kind of hybrid solution the optimal way is to use different methods. Products located before the decoupling point use fixed order intervals since they are driven by a MTS strategy. Products located after the decoupling point have to be further evaluated based on their attributes before deciding the optimal lot size method. This entails a requirement of a storage area connected to the decoupling point for those product families. Therefore, a larger problem arises since space is limited as it is today. Meaning, a transition from project-based planning to product-based would most likely need to be brought up with management to invest more or conduct larger changes at the facility. Regardless of the chosen lot sizing strategy, it is important to account for the high number of defects occurring in both production lines, particularly in Production Line A, where the issue is more prominent. By identifying which products or materials are most prone to defects and procuring larger batches of those specific items, many production disruptions could be mitigated.

6.2.4 Case company capacity prioritisation

For the case company transitioning toward this hybrid planning approach, capacity allocation and prioritisation are important aspects to consider in achieving a balanced and responsive production system. After segmentation into product families, categorisation towards MTS, MTO, or hybrid, and the implementation of a decoupling point, the prioritisation needs to be considered. MTS products are continuously produced whenever there is capacity available, thus, prioritisation is not considered as important for line A where a more upstream decoupling point is recommended. Rafiei & Rabbani (2011) suggests prioritisation by three criterias in a MTS environment, being contribution, reputation, and potential future sales, with highest combined value being prioritised. Similar criterias could be implemented at company Alpha, these criterias have however not been addressed in this study and will need to be analysed to generate a prioritisation template that can be used on the relevant products in line A and B. Therefore, specific prioritisations for each respective product will not be mentioned in this discussion. Other ways of prioritising suggested by the authors would be by what expertise currently is available by the operators. As the expertise is identified as a current bottleneck, utilising the most experienced ones time could potentially decrease the impact of the shortages when they occur. Also prioritise products that have the lowest inventory levels.

Prioritisation is however essential for MTO orders, where capacity is more limited and demand is driven by actual customer orders. Production line B is suitable for this MTO strategy because of the limited capacity, storage space, and long lead times. Rafiei & Rabbani (2011) suggested a prioritisation on MTO orders by four criterias which are ranked upon by either a high or low score. The criterias used were customer profit contribution, potential purchasing of the customer, order size, and order purchase range. All mentioned could be considered as worthy and suitable criterias to the case company. As previously mentioned however, these criterias have not been addressed and therefore can not be used in this discussion to position which products should be prioritised. These criterias do however seem suitable for the case company who will need to analyse and implement this either before or in a later stage of the transition. This since many orders are accepted and an infinite resource is planned after.

Based on the collected data and literature another approach towards production line B is suggested regarding prioritisation. It has been perceived that operators sometimes have to wait for material and therefore do not have an ongoing job and precious time is wasted. It is currently managed by letting these operators work on smaller projects in the meantime but eventually ends up further delaying the main projects. As product D has five variants that are very correlated, it could be beneficial to educate all operators on product D's production steps. Thus the less experienced can adhere to those processes while the more experienced can focus on the more demanding processes. Following this way of working, prioritisation can be done by weighing the operators' knowledge and expertise. Thus less experienced operators focus on the standardised processes which frees up more time for the experienced ones to finish their tasks.

6.3 Post transition

This segment will discuss what potential effects the transition will have on mainly today's capacity problem and the rescheduling issue. It will also present what previous case studies conducted in similar environments have found regarding effects of a transition. Also, a discussion of what future company problems can be beneficial to address and slightly how to do it.

6.3.1 Effects on the capacity

When referring to capacity planning Jonsson & Mattsson, (2009) state that the goal is to balance the demanded capacity with the available capacity. In other words, matching the need of capacity with the capacity the company can offer. In the situation of case company Alpha and all other companies which want to earn profits, it is wished to the extent it is possible to not turn down any new customer orders. Therefore it is not “possible” to adjust the demanded capacity, meaning the supply of capacity is the only variable which can be adjusted. Furthermore, Jonsson & Mattsson, (2009) refers to the supply of capacity as both time and size sensitive. If the supply is too low, either the volumes or timing of the delivery can be adjusted. For case company Alpha it could be beneficial to adjusting the time dimensions of some customer orders first as far as possible or allow. This since the higher demanded volumes might not last forever. However, if not possible the volumes or size needs to be adjusted. This is what is done by this thesis through the implementation of a hybrid production structure which is referred to as the product-based way of production planning.

When implementing a hybrid structure, meaning certain modules of products are to be produced towards a stock, the planned capacity will be affected positively. In Line B, the suggestion that product D or some of its modules should be produced as MTS is previously mentioned. As earlier described, the production of this product should to the extent possible only be produced when the MTO products are few or when new/less experienced personnel is available, without any other work tasks. This to cover today's unutilised workforce greeting an idle production which occurs due to few orders receiving the fully reserved status. This means that the overall planned production most likely should fall slightly, allowing a more realistic visualisation, see grey area in Figure 12. It would also provide a more clear picture of what needs to be done enabling easier planning work for the production planners to match the workforce with the projects. This is because there are fewer MTO orders in the system since the MTS orders only are produced when time allows. Additionally a MTS system brings forward a more stable schedule enabling the planning work further. This however, is only in the mature projects since the immature is constantly changing and only using a MTO structure. Regarding the MTS schedule stability, it is heavily dependent on the quality of the forecast (Jacobs et al., 2018).

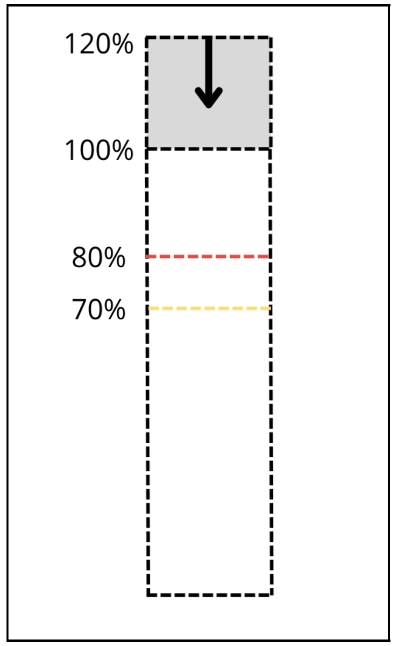

Figure 12: Representing a capacity bar at a production Line.

A similar scenario would occur at Line A. The difference is that here, more products are produced with a MTS structure, meaning they can not only be produced when time allows. Since the backlog is very large, the risk of zero MTS orders passing through are increased. Therefore, it could instead be beneficial to divide the products with different flows (MTO/MTS) providing a more clear view of what MTO products need to be done. However, important here is that the volumes of the MTS products are relatively high to ensure an aligned capacity for the line employees responsible for those products. Otherwise a similar situation would occur as in Line B today with unutilised capacity. Furthermore, this would allow the operators to be more specialised on "their" products. If a couple products are transformed from MTO to MTS, fewer products are in the portfolio of an operator which could shorten the lead times for producing but also allowing errors to be found earlier. This would in turn lower the production costs for mature projects which utilise MTS products, with however, at the expense of higher inventory cost (Jacobs et al., 2018). It is important to mention that this most likely would reduce the workforce flexibility over time. A decrease in flexibility could mean that company Alpha increases the risk of high costs if the intake of customer orders suddenly decreases, this is however not a scenario in the foreseeable future. An additional issue that company Alpha might experience is even more problems with the inventory space issue, requiring more storage space.

However, an important aspect to consider of this transition which occurs in Line A is that MTS products are allocating capacity which could otherwise have been used on MTO products which are higher prioritised. Therefore, it is of high importance to follow the previously mentioned capacity allocation suggestions to avoid producing the wrong units. Although, even if the risk of allocating capacity occurs, the lead times towards customer decreases, which is arguably weighted more than the risk. To summarise the discussion above the overall capacity which today is planned way too high will probably decrease as a positive effect of the transition. Also the idle production at Line B would probably decrease, since more work is available, meaning a more correct capacity graph would be provided. This can be seen from Figure 13.

Regarding the measuring of capacity and reservation status, if these problems are looked over as proposed in the pre-transition chapter also this part of the graph would be improved. Although, this is not explicitly connected to the transition from a project-based way of working towards a product-based way, through implementing a hybrid structure.

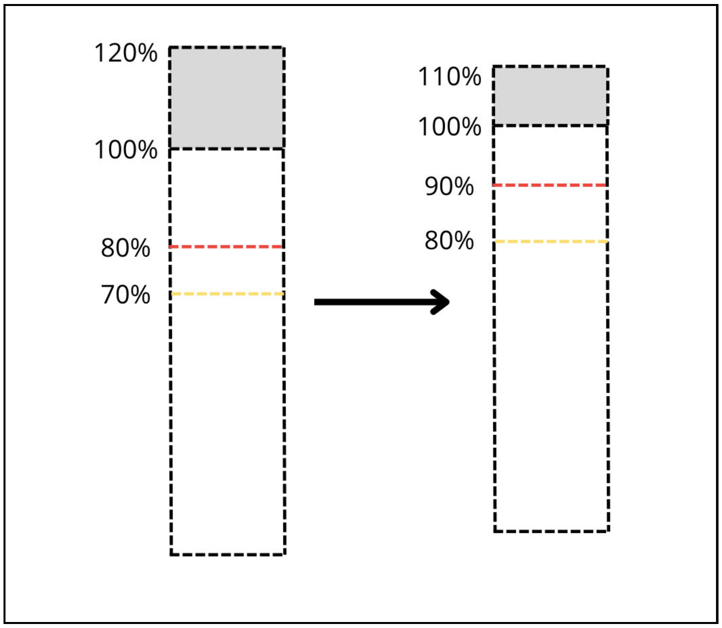

Figure 13: Representing the effects occurring on the capacity bars if the transition towards project-based way or working is done alongside the smaller changes regarding reservation status and capacity measurements is conducted.

If also adding a more theoretical perspective it could be useful to consider the usage of lead or lag strategy. This is not directly connected to the transition but it could be beneficial to implement a lead strategy for the MTS products as Kiran, (2019) argues it is a more proactive strategy. While the MTO products could use a lag strategy, not producing anything before the demand arises, which according to Jonsson & Mattsson, (2009) is more reactive, fitting the MTO structure well. Further strategies presented by Jonsson & Mattsson (2009) could be to combine the level strategy with the lead strategy used on MTS products to smoothen out the forecasted values. Then also combining the chase strategy with the lag strategy used for MTO products to always strive to deliver as customers wish. Regardless of a transition or not, theory provided by Jonsson & Mattsson, (2009) suggests capacity requirements planning each order in more detail and for keeping it updated. Also Kalinowski et al., (2018) discusses the usage of forward scheduling which could be beneficial for MTO products since it schedules orders as early as possible and those should be prioritised.

6.3.2 Effects on rescheduling

One of the major challenges identified in the current production system and way of planning is the extensive rescheduling, mainly originating from material shortages, inaccurate lead times, and capacity constraints. In the current project-based setup, every customer order triggers specific planning and production activities, leading to a highly dynamic and often unstable production environment where priorities shift frequently. This situation forces planners to continuously reschedule operations to adapt to the changing conditions, causing inefficiencies and production delays. By transitioning toward a hybrid production system, where certain modules and sub-assemblies are produced based on forecasts (MTS) while maintaining flexibility for customer-specific adaptations (MTO), the frequency of rescheduling issues are expected to decrease significantly. Standardising production for selected modules and manufacturing them in advance will lead to a more stable base load in production. This, in turn, will reduce the amount of critical orders, aligning the production better with the principles of time fences and the importance of stabilising frozen and slushy zones as discussed by Jonsson & Mattsson (2009).

Moreover, with improved segmentation and the introduction of decoupling points at intermediate stages as discussed, material availability will become more predictable. Having semi-finished goods or modules ready in inventory mitigates the risk of production being postponed due to materials arriving late. Another positive impact is connected to the capacity planning improvements outlined earlier. By limiting the infinite resource assumption and introducing finite capacity checks, the organisation can better align production schedules with actual available capacity. As a result, rescheduling due to capacity overloads, which currently is a major problem in production line A, is expected to be reduced. However, it must be noted that while rescheduling is likely to decrease for the modules transitioned to MTS, customer-specific operations closer to the decoupling point will still involve a certain level of rescheduling. This is unavoidable in MTO production and will need to be managed with thorough planning and buffer strategies such as time fences and limited SSs wherever it is possible.

Additionally, when considering and restricting the material issues which were identified in the hanging fruit matrix as major projects, it will significantly reduce the frequency and impact that rescheduling will have. This does however lay outside of the production planning transition but will result in great positive effects for the rescheduling and organisation overall. In conclusion, the transition toward a hybrid production approach will not eliminate the need for rescheduling but it should however significantly stabilise the production planning activities, greatly reduce rescheduling frequencies, and improve overall production efficiency. These effects align closely with findings from studies such as Pereira et al. (2022), who highlighted that hybrid strategies can greatly enhance operational performance in several areas.

6.3.3 Additional effects

A transition of the production system along with other smaller proposed changes effects on the planning structure will probably occur. How the changes can affect the production planning is not obvious nor commonly researched. However, based on the knowledge of the authors regarding the company structure and the different frameworks it is reasonable to argue that the decoupling point can be positioned between the product and project planner for certain products. As proposed in chapter 6.2.2 the decoupling point for product A can occur further downstreams after the production, entailing a make-to-stock system. Meaning the product planner works more towards this MTS structure while the project planner focuses on the MTO approach regarding the final assembly. This in turn, entails that the product planner will spend more time on reviewing forecasts and collaborating with the department responsible for forecasting. Alternatively is that the product planner's needs to develop and evaluate more detailed forecasts themselves.

Therefore, the communication towards project planners might both change in subject but also decrease. The reason for the decrease is since project planners now are able to look up the status of the products in the system since they should appear at the storage. Due to this, the interest conflicts between project and product planners might also increase further, since the different production systems. Although, most of the structural changes will therefore occur at the product planners level for the appropriate products. The project planner will continue more or less with the work which is done today since no immature products will be produced as MTS and now top level products have been identified as appropriate for MTS.

While this study primarily focused on mapping planning processes and identifying implementable improvements, valuable insights were also drawn from previous case studies on similar hybrid production transition. These studies, though differing in industry and scope, provide an important benchmark for potential outcomes that go beyond immediate planning efficiency gains. Several studies observed significant increases in delivery precision following the transition from purely MTO to hybrid or partially MTS setups. In one case, delivery precision improved by up to 20% (Rafiei & Rabbani, 2014), while others also noted significant improvements even if not quantified in detail (Perona et al., 2009). Such improvements are especially relevant for the case company, where reliable delivery is critical due to the complex nature of the projects and the need to meet tight deadlines. Furthermore, these studies consistently reported an increase in cost savings, ranging from 10% to 25% (Pereira et al., 2022), and in one case as much as 36% (Perona et al., 2009). These savings were attributed to more stable lot sizing, better inventory planning, and a reduction in reactive adjustments such as overtime and critical orders. Given the current high rate of rescheduling and fire extinguishing observed at the case company, similar cost reductions could potentially be realised, especially if the identified changes in lot-sizing and decoupling strategies are implemented effectively.

In terms of lead time reduction, one study found improvements from 21% (Pereira et al., 2022) up to 47% (Rafiei & Rabbani, 2014), showing the value of better order segmentation and more proactive inventory strategies. These results align well with the current case, where inaccurate lead times were identified as a planning issue. A more standardised and data-driven planning approach, as proposed in this thesis, would support continuous lead time improvement. Moreover, two studies reported a significant reduction in backlog levels (Rafiei & Rabbani, 2011; Rafiei & Rabbani, 2014), a benefit of particular relevance to the case company, where backlogs have become increasingly difficult to manage. One study also reported fewer shortages of semi-finished goods (Rafiei & Rabbani, 2011), attributed to better planning and SS strategies, an issue similarly observed in this study's findings. While these outcomes cannot be guaranteed, they offer a strong indication of the potential positive effects associated with implementing the proposed changes. If the case company successfully adopts a hybrid planning approach, emphasising better segmentation, appropriate decoupling points, adaptive lot sizes, and established capacity prioritisation, many of these reported benefits could also be realised to a certain degree.

6.3.4 Future improvements

It is also important to address the problems and improvement areas in the upper half of Figure 9, which have a larger implementation difficulty but, depending on the placement, could have considerable impact. Therefore, the problems within major projects will be discussed but money pits will only be touched upon. However, those problems stand outside of the transition and could therefore be addressed afterwards to avoid starting too many projects at the same time stealing resources and energy from the main transition project.

The first and major identified problem is the way MRP plans against an infinite resource. When discussing and evaluating this problem and its improvement areas, it was identified to result in a major impact as it could potentially negate the majority of rescheduling and the related capacity constraints. This is when referring to production line A as the capacity planning is the major issue. Production line B would also see considerable improvements but has other problems with potentially larger impact. Implementing a limit with the available capacity towards the MRP system is considered hard to implement as available capacity needs to be measured but also gradually updated to maintain all future changes made to both the production lines and the products produced.

Another important problem identified was the issue of material quality. Material quality problems can arise from both internal- and external processes. Internal could be improper material handling in production but also too high requirements on the products or poor performance from engineering. Which of those or if a combination of all is the problem is outside of the thesis scope and can not be said. The external processes of the quality could be defects but also bad quality from the suppliers. It has however been shown that the results are increased scrap rates, rework, and production delays. Solving this problem is therefore very difficult as several areas need to be improved where improved material quality requires closer collaboration towards the suppliers. To improve the internal processes, a better communication in between production and configuration management who designs the products is needed, additionally, meetings to align and discuss the production processes and the possible too high requirements are also needed. The possible impact is therefore also very large as all identified connected problems could be not only minimised but possibly negated.

Material availability issues were also highlighted as a critical area, which is connected to the limited warehouse storage. Another cause is the supplier delivery precision problems. Literature points out that synchronised supply and demand are crucial to maintaining a smooth and well functioning production system (Jonsson & Mattsson, 2009). As the storage capacity problem inhouse is well known but difficult to regulate at the time, it can not be considered as a solution, although it is recommended to increase the storage to fit today's capacity requirements. Therefore, the supplier delivery precision needs to be improved which entails a need of improved cooperation with procurement. As this has been discussed in the cross-functionality chapter it will not be further addressed here. The difficulty of this improvement is high as it requires continuous meetings and discussions from several departments. The potential results on production and planning are therefore substantial.

A noteworthy area for future improvement concerns the accuracy of lead times in the planning system. While current lead times generally support planning activities, there is potential to enhance their precision, particularly as both production processes and products change over time. As these changes occur, the alignment between planned and actual lead times can greatly diverge, which may affect the efficiency of planning and execution over the long term. More accurate lead times would further strengthen the reliability of production planning by supporting better synchronisation across activities and reducing the risk of rescheduling or bottlenecks. That said, having updated lead times is difficult, as it requires continuously updating them when modifications within production and products occur. Although implementation can be moderately demanding due to this maintenance, the long-term benefits to planning accuracy make it a valuable area to revisit periodically.

Regarding the money pits, it is not worth investing neither money nor time into as the degree of difficulty exceeds the potential impact to the organisation. Interest in conflict was the first identified problem where the different planners had different interests such as the project planners prioritising the finish date while product planners prioritising the production flow. Although the problem is well recognised, it would be difficult to solve since it would require a restructure of either the project structures or implementation of shared KPIs that everyone can follow. Additionally, it offers relatively low direct impact compared to other problems identified with high difficulty. However, the upcoming implementation of a hybrid production setup, where a portion of products and components could be MTS rather than MTO, is expected to mitigate some of this conflict. A result of this transition could be that planners can work within better-defined scopes, potentially reducing tensions between project- and product-driven planning. When discussing and evaluating time fences and its improvement areas, it was brought up that more restrictive time fence rules were implemented a while ago. It did however often get ignored by the different planners since it often needed to be bypassed to pass the finish dates of the projects, making it a failing project from the past.

7. Conclusion

The thesis aimed to explore the transition from project-based production planning towards a higher degree of product-based production planning. In other words, the transition from a pure MTO structure to a hybrid, allowing some product segments to be produced with a MTS structure in a complex manufacturing environment. This was done by first mapping the current production system and planning processes to understand the coordination through mainly observations. It identified the problems of today's structure in order to suggest changes required to conduct the transition through interviews and research. Furthermore, it analysed the potential effects the transition could see based on similar cases done previously. Competition steadily increases and puts more pressure on manufacturing companies to deliver quickly while still allowing a high degree of customisation. This thesis can help to suggest how to adapt and stay competitive by modifying the planning and production structure and collaboration within the organisation.

RQ1: How is the production and planning set up and how do they coordinate?

The study revealed that the company operates largely under a project-based planning, also referred to as a MTO structure, and provided insights into what segments could benefit from changing the structure. It also revealed that production plans are created with the assumption of infinite resources available, leading to mismatches between planning and execution, creating frustration and irritation between the different planning roles and the production units. Furthermore, projects existed in two forms, mature and immature where the main difference was the degree of involvement from the project planner. Coordination between planning and production is further complicated by inconsistent material availability, capacity constraints, and communication difficulties all of which increase the need for rescheduling resulting in reduced efficiency.

RQ2: What changes within planning can be made to transform from project-based planning to product-based planning?

Building on the insights collected on the case company, as well as theoretical models and previous findings on transitions conducted in similar environments, the study proposes a transition toward a product-based planning approach, introducing a hybrid strategy. Some products with high variation and extensive customisation will continue to follow an MTO flow, this mainly regards production line B with the exception of product D. While other products, mainly in production line A, which are particularly standardised modules and lower-variation products, will move towards a MTS strategy. This transition is proposed by segmenting products based on predictability and customisation level, determining the optimal decoupling point, adjusting lot sizes, and introducing a framework for capacity prioritisation. Other proposed changes outside of the transition such as conducting a more correct capacity measurement, using both safety time and stock to a wider extent, are recommended to be addressed beforehand in order to achieve good results. Since this thesis has been conducted on an industry stamped by very high requirements and complex products, it has shown that a transition in production strategy needs to carefully address the segmentation of products. Which contradicts previous studies to the degree to which the MTS strategy is possible. Furthermore this thesis has researched beyond the transition of the production and proposed a low hanging fruit matrix in order to prepare the organisation for the main transition.

RQ3: What potential impacts will these changes imply on production and planning?

The potential impacts of this transition are significant through aligning planning more closely with actual production capabilities and introducing flexibility through hybrid strategies. Company Alpha could experience a more accurate and stable capacity planning, leading to a better match between planning and execution. Additionally, providing a more stable production schedule, reducing the amount of rescheduling done. This could ultimately improve the conditions required for a MTS strategy. Previous research on a transition in similar environments has shown to improve delivery performance, reduce operational costs, reduce the backorder log, and strengthen cross-functional collaboration. Additionally, this study has contributed solutions for company Alpha to achieve better material availability, stable production and planning flow, and better collaboration between roles and departments.

If successfully implemented and fine-tuned, this hybrid strategy could be adapted beyond the reviewed products to other projects and potentially to broader parts of the organisation. By extending these concepts, additional improvements in planning stability, production efficiency, and customer responsiveness could be achieved, contributing to a more resilient and scalable production system for the organisation overall. However, this transition is not done without experiencing obstacles and hard work is required.

7.1 Limitations and Future research

While this study provides valuable insights into the transition from project-based MTO planning to a more product-based MTS approach, several areas require further investigation to deepen and broaden the understanding of production system transitioning in various environments. The identified problems presented in the low hanging fruit matrix is possible to further investigate and provide actual calculated numerical values, for example a suitable safety stock or safety time etc. Also continuing a deep dive into the different products to identify what segment they adhere to by studying the product properties. This would allow for an exact determination of the decoupling point and what lot size to use. Further suggestions is to continue the broadening of the study and include more parts of the organisation to achieve the full scale effect. More benefits would be to further introduce a more modular production and look into the possibilities of standardising the products in order to further improve the conditions regarding MTS production.

Other possible areas to investigate is to connect it more to procurement, the planning department generates all of procurements work. This study identified several challenges regarding the collaboration between procurement and planning. Therefore a similar study conducted on the procurement department could be of value to the company. Additionally, trying to figure out the consequences this transition will bring to the various procurement roles. Furthermore, this study was limited to one case company with a time frame of half a year was set. It could therefore be interesting to further study the transition on the broader industry to be able to better compare the results and triangulate the most common problems. Another limitation was the confidentiality of information, which prevented calculations of the situation today and what the potential effects would cause.

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