Vaasan yliopisto
UNIVERSITY OF VAASA

Juha Lehtimäki

Order management and production control development in MTO production

Case study

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Tekijä:	Juha Lehtimäki
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TIIVISTELMÄ:

Tuotanto on yksi oleellisimmasta vaikuttajista lukemattomien yritysten menestyksessä. Yritysten pärjääminen kilpailluilla markkinoilla on usein riippuvainen heidän kyvystään tarjota tuotteita ja palveluita kilpailukykyiseen hintaan, ja hinnan kilpailukyky on puolestaan usein suorassa yhteydessä tuotannon prosessien tehokkuuteen ja hallintaan.

Tämä tutkielma on tehty yhteistyössä yrityksen kanssa. Työn tarkoituksena on määritellä optimaalisen tilaus- ja tuotantoprosessien osatekijät heidän markkinoillaan, analysoida tilaajayrityksen nykytilanne tämän perusteella sekä löytää kehitysmahdollisuuksia yrityksen tilaus- ja tuotantoprosesseissa. Työ on toteutettu empiirisenä tapaustutkimuksena ja tutkimuksen aineistona toimii aiheesta toimitettu kirjallisuus, haastattelut, tutkimuksen aikana tehdyt havainnot sekä data-analyysi.

Tutkimus paljasti monia haasteita yrityksen tilaus- ja tuotantoprosesseissa. Isoimmat haasteet liittyvät tilauksien ja työntekijöiden roolien organisointiin, sillä epäjärjestelmällinen työskentelytapa vaikeuttaa prosessien tehokasta toimintaa. Tuloksien pohjalta huomattiin, että yrityksen tulisi selkeyttää tilausprosessin kulkua ja organisoida tilauksia keskitetymmin. Tällaisella toimintatavalla koko tilaus- ja tuotantoketju selkeytyisi kauttaaltaan.

Lisäksi yrityksen tulisi kehittää sen tuotannonhallinnan työkalujen käyttöä. Puutteellinen tilausten organisointi, tuotannonhallinta ja raportointi vaikeuttaa huomattavasti aikatauluttamista ja tuotannon tehokkuutta. Kehittyneemmällä tuotannonhallinnan työkaluilla yrityksen tuotantoprosessista olisi mahdollista saada sujuvampi.

Tutkimus vastasi alussa sille asetettuun tutkimuskysymykseen ja muihin vaatimuksiin, joten sitä voidaan tältä osin pitää onnistuneena. Tutkimuksen pohjalta on myös mahdollista jatkaa lisätutkimuksia aiheesta eri näkökulmalla tai tarkemmin.

AVAINSANAT: tapaustutkimus, valmistus, tilausten hallinta, prosessikehitys, tuotannonohjaus

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Author: Juha Lehtimäki
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ABSTRACT:

Production is a vital part for many companies, one of the key pillars of a successful business. The survival of companies in a competitive market often depends on their ability to provide goods and services at affordable prices, which is a direct result of efficiency in production processes and good production control.

This study is conducted in collaboration with a case company. The purpose of this study is to define the factors of successful production order and production management in their business, analyze the case current situation of the case company, and based on these, find improvements in its order and production process. The work is an empirical case study and it uses data from a literature review, interviews, observations and data analysis.

The results of the research revealed challenges related to order and production processes. Major challenges are related to how processes and people are organized. Lack of a consistent way of working is a good base for inefficient and unclear processes. Results show that to reduce these challenges the company should clarify the flow of the order process and centralize all production orders to one place. This approach would clarify the process for all parts.

The research findings also prove that the company should develop its production control tools. The lack of order visibility, production management and reporting of current and historical data of production negatively affects scheduling and production efficiency. With more developed production control tools, the company would likely gain benefits in the production process.

The research was completed as it was planned, and therefor fulfills the requirements of the thesis. It also offers a great opportunity to continue research in the future about the same topic with a more specific point of view.

KEYWORDS: case study, manufacturing, order management, process development, production control

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Abbreviations

EDD = Earliest Due Date

ERP = Enterprise Resource Planning

KPI = Key Performance Indicator

MES = Manufacturing Execution System

SPT = Shortest processing time

WSPT = Weighted Shortest Processing Time

1 INTRODUCTION

Production is a vital part for many companies, one of the key pillars of a successful business. Companies' survival in a competitive market often depends on their ability to provide goods and services at affordable prices, which is a direct result of efficiency in production processes and good production control. (Geektonight)

By optimizing production and order processes, companies reduce costs, eventually impacting the financial result. Often a well-flowing production process also brings other non-financial benefits, such as improved clarity, reduced number of failures, and better visibility for management.

This thesis will study how production control and order management could be developed in the case company's production process. The study is about overall performance of production and order control, reflected on the case company's environment. The case company of the study is Inlook, a leading Finnish interior building solutions supplier. The specific area of study in the company is their own production of wood and aluminum products.

Currently there is a high variability in production and ordering processes. In many cases, they are based on manual and inconsistent controlling methods, like emails, handwritten instructions or various excel sheets, and in the execution of those all trust relies on production workers' expertise. This has worked so far, but the company is willing to improve that as a part of wider logistics and production rearrangement plan.

A better production planning and control system could help to control production and scheduling, increase consistency, provide shorter production times, and monitor level of quality and efficiency in the long run. Volatility of order volume is high, causing problems to effectively adapt to changing production requirements. High volatility in the current way requires a lot of flexibility to maintain a stable workload for all employees.

First part of this study is theoretical, including the literature review of studies from the topics related to this study. The basic concepts and paradigms of the study are also explained to the readers that are not already familiar with the topic.

Second part is practical study part, where the current situation in the case company is clarified and statistics from the company is studied, along with needed research and other material collection.

Based on all the collected data and analysis of literature review, the section is followed with a result part, that includes suggested actions to develop the situation in the future.

1.1 Research question, objectives and limitations

The company has recognized some challenges related to their production process. First of them is the overall control of the order process and different phases related to it. From their perspective order process is not standardized in a way where it would benefit all parts.

Another challenge is production control, especially how it should be organized in a way where control would be in somewhere else than shop floor level. This would clarify the responsibilities of all parts. Third aspect is work control related to scheduling and workload of employees, as a better control of ongoing and upcoming works would most likely improve project management and the production process.

The goal of this master's thesis is to find development aspects for order and production processes in the case company.

Research question is defined as follow: How should order and production processes be controlled and managed to provide better performance and service level?

Objectives for the research are:

- Literature review on papers studying the problem
- Statistical analysis of the case company's production orders
- Interviews with order management people
- Description of ideal process and material flows of production and required materials
- Suggestion of the best solution in the framework of the research

The study is limited to the case company's own production that takes place in their production unit in Helsinki. Thus, the study may not be applicable on other production processes or different product types that have different parts of the process or different material flow. The study will not examine or comment on other parts of the process than production and parts that are directly related to it. Sales, project planning and installation processes are examples of phases that are not included in the study.

1.2 Case company

The case company Inlook is a leading Finnish service company supplying interior building solutions. The company, originally known as E. Hiltunen Ky, was established in 1967. During its 50 years history it has been known as a trusted partner in high-quality, functional and impressive interiors. Inlook corporation employs more than 500 employees in four countries, Finland, Sweden, Estonia and Lithuania. Its biggest market area is Finland. The combined turnover of Inlook's markets in 2020 was almost 85 million euro. (Inlook-konserni, 2021b)

Operations of the group are divided into construction services and industrial services. Construction services include a contracting of ceilings, drywall partitions, partition walls, full-service interior construction services and material sales in Finland and Sweden. Industrial service offers powder coating services in two paint shops, located in Estonia and Lithuania. (Inlook-konserni, 2021a)

This work focuses on Inlook's own wood and aluminum glass products, which are manufactured in their production unit in Helsinki. The production unit supports the operations of construction services, which means that all its customers are internal customers. Manufactured products are based on a few different main product types, which are then slightly modified to suit each different case and customer's requirements. Products eventually end up to external construction projects, but all direct contacts of the production unit are internal project managers.

2 LITERATURE REVIEW

2.1 Production

2.1.1 What is production?

Production is a function where a factor of production is transformed into goods that are then set available for the market (Haverila et. al., 2009, s. 351). For companies that rely on production, competitiveness is a key factor. It is highly dependent on companies' capability to produce new products or services to the market. Most successful companies share a few similarities in their production operations. They can produce their products rapidly, with great quality but keeping their operations flexible. They also have professional staff with a lot of knowledge. (Kajaste & Liukko, 1994, s. 1)

In spoken language production and manufacturing are often mixed with each other. However, production is a much larger concept than manufacturing. Production consists of all operations that are required to deliver a product or service to market, while manufacturing is only a process where a shape or condition of material is changed, or materials are connected or disconnected from each other. This means that manufacturing is one, often vital, part of production. Examples of other subparts of production are production management, order process, defining the specifications of the product and material procurement. (Haverila et. al., 2009, s. 351)

The ultimate purpose of production is to fulfill the needs of business. The production itself does not make any value if it is not utilized correctly in the business. There are three different methods of production. A company cannot choose its mode of production freely because it is determined by production volumes, product structures, manufacturing techniques and distribution channels. (Haverila et. al., 2009, s. 353)

2.1.2 Production types

Based on output type, products are divided into two categories: standard products and products that are produced based on unique order. Standard products are always the same, and there are no possibilities for clients to make justifications. This study focuses on the other type, where specific product definitions are based on customer order, making each product somewhat unique, but they all have the same basic concept of how they will be made.

Another way to define production is to define where the production signal is coming from. In push production products are manufactured to stock with pre-planned pace, without a specific order signal from the client. On the contrary, pull production means production type where production start only when an order signal has been received from the other end of the product's supply chain, and there is an actual need for the end product. (Haverila et. al., 2009, s. 354)

A third way to categorize production is based on batch size. With this style production methods are divided into job shop production, batch production and repetitive production. Job shop is production where all produced goods are designed and produced based on customer’s requirements. Often job shop production is referred to as a project. Pure job shop factories are relatively rare because it is inefficient to produce single products. (Saari, 2006, s. 69-99; Haverila et. al., 2009, s. 354; Kumar & Surehs, 2009, s. 4-6)

In batch production one batch consists only of similar products. Batches are also reoccurring occasionally, which gives a possibility to learn from the past, making it more efficient over time. Some typical examples of batch production are fashion and food industries, where large batches are produced regularly. Production planning and control in batch production are more important than usual, because often there is a great connection between the production batch size planning and efficiency of the production. (Saari, 2006, s. 69-99; Haverila et. al., 2009, s. 354)

Repetitive production is a manufacturing process where manufactured products are highly standardized, and the assembly line is designed specifically for one product type. This allows higher efficiency and lower cost per unit in the production process. A high level of automation and robotics are often important tools in repetitive production. An example of repetitive production is a car factory. (Saari, 2006, s. 69-99; Haverila et. al., 2009, s. 355)

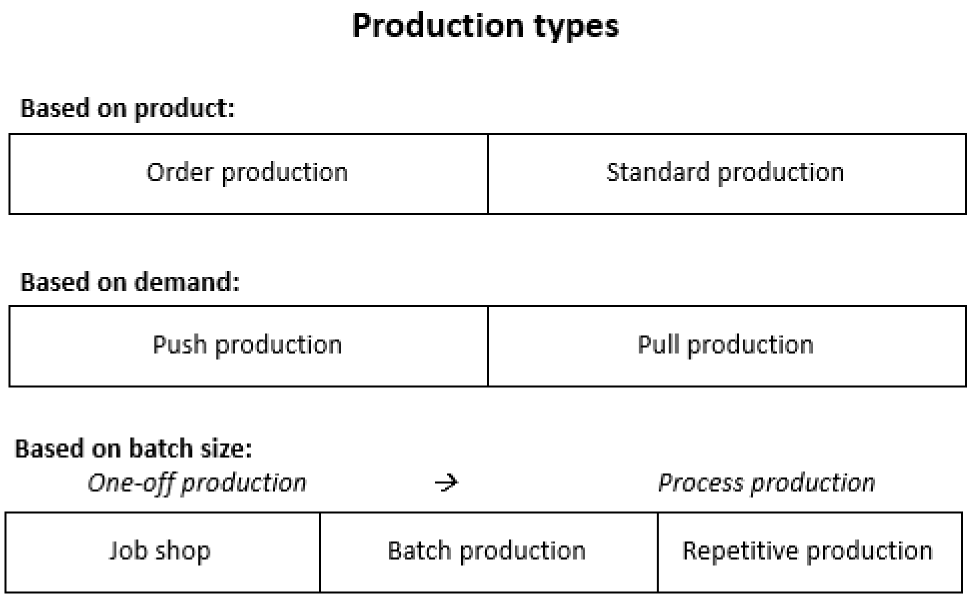

Figure 1. Different production types

2.2 Order management

2.2.1 Requirements of order and successful order management

Order-based production requires two essential parts of information, a specification of what needs to be produced and when it must be finished. Order management is controlling those activities, holding needed information about products and promised delivery dates, and ensuring that everything is done accordingly to fulfill the requirements of the customers' needs. According to Forza & Salvador (2004, s. 273-291; 2002, s.87-98) order management can be divided into order acquisition and order fulfillment phases. The challenge of order acquisition is the interface with the customers, and a great variety of requirements from customers' side. In the fulfillment phase, the challenge is to handle those requirements of products and delivery schedule. (Tehniälä & Ketokivi, 2012, s. 173-206)

A typical risk of order acquisition is a possibility of communication errors between customer and producer. A customer might get confused with the offered variety of available options, thus leading to mistakes in configuring the products (Huffman & Kahn, 1998, s. 491-513). To ensure a smooth process all the way from order to finished product, the tools and processes of an order transaction should support the capabilities of manufacturing. This requires an effective flow of information between all functions within the company. A failure in this process is likely to lead to errors and waste of resources.

One option to reduce problems related to order acquisition is to control orders with the help of technology. By using standardized order platforms, for example computer programs or order sheets, it is easier to control a product configuration. If the limits for each product type are set, this will manage orders and eliminate orders that do not fit into the manufacturing process (Forza & Salvador, 2002, s. 87-98). Tools like this can also help a customer to demonstrate their needs to the supplier (Huffman & Kahn, 1998, s. 491-513).

Scheduling of product finishing is another thing to consider. In order manufacturing, required materials can be order specific, and their delivery lead times can vary widely. This, in addition to capacity utilization at the time of order acquisition, has a significant influence on how fast products can be manufactured and delivered.

This means that a fixed lead time quotes are challenging, leading to ineffective delivery date promises. If a lead time of material is fast and current production capacity utilization is low, a fixed lead time would show off longer lead time than it could be. On the other hand, if production capacity is highly utilized or raw materials are long lead time products, a fixed lead time would be too optimistic. (Proud, 2007).

2.3 Production planning and control

2.3.1 Production methods and tools

A production process is thought to be one of the most important functions of an industrial company. The biggest decisions and problems are often related to controlling and developing the production process. (Haverila et. al., 2009, s. 350)

Production methods and management has evolved significantly ever since industrial production started. One of the first production methods was based on work done by an individual craftsman and the process around it was uncontrolled. This offered high flexibility on product variety, but the outcome was highly dependent on the individual’s skill.

Since then, the world has seen phases when mass production was at its peak, before just-in-production took over it. Later lean production and network economy showed their strength, and they have kept their positions to this day, although there are changes happening all the time, and it is only a matter of time when new ideas will arise and start dominating. (Haverila et. al., 2009, s. 359)

No matter what method is chosen, the aim of it should be cost-efficient, high-quality production with high flexibility and time reliability. It should also support the company's production strategy in the best possible way. In larger examinations, there are also elements on how production should carry its social responsibility, by taking care of product safety, work environment and surrounding environment. (Haverila et. al., 2009, s. 357-358)

Reaching all these targets in practice is often challenging, because some of these are contradictory with each other. For example, increasing flexibility might lead to cost increase. Also, different products can have different requirements of production, so it might be difficult to find a production method that suits these different demands. This means that in many cases production models are compromises that provide best support for different products.

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The difference between MES and ERP systems is their core idea. ERP is planned to serve wide variety of business demands with one tool, including invoicing, warehousing, human resources and so on. This wide overview offers a great overall control of the business, but often other side of that is its harder adjustability and editability. On the other hand, MES is a tool that is focused on the shop floor and is often custom-made or at least easier to adjust for production purposes. It does not try to offer a large scale of different operations but tries to focus purely on manufacturing and its direct activities. MES solutions generally provide visibility for production statuses, offer traceability to a manufactured product, collect the performance data of different steps during the process, and offer a place for operating instructions. (Saenz de Ugarte et. al., 2009, s. 525-539)

MES systems can be either stand-alone solutions for one place, or integrated with other business systems, engineering systems or maintenance systems across multiple production plants or enterprises. Integration of different systems, generally with ERP systems is a good way to share information and increase the added value for both systems. With accurate data flow it is easier to plan and predict business, optimize inventory levels, and have a good overall collaboration between different stages of the process. (Abel, 2018).

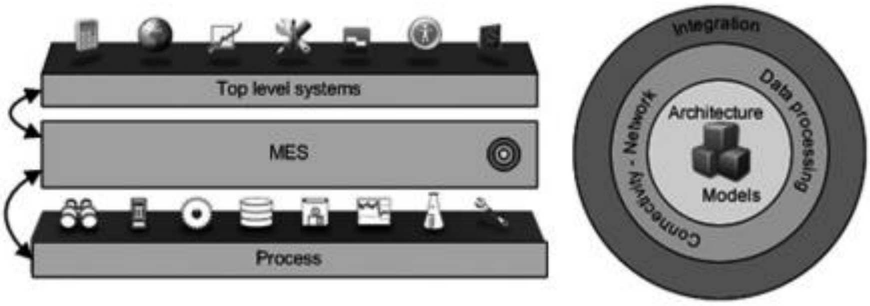


Figure 2. MES environment and its layers (Saenz de Ugarte et. al., 2009, s. 526)

In all information systems, data and its surroundings are the core for effectiveness. If data is incorrect, or not available, these systems will not be able to analyze it and function properly. That also means, that all these benefits these systems could afford are not about to realize.

2.3.2 Performance and scheduling

What should be the basis for all actions in a company? According to Hannus (1993, s.71-72), for every company there are three stakeholders that are having visions and goals for the company from their own perspective: customers, owners, and employees. Customers appreciate high quality and cost-efficient products, owners expect good profit and employees hope possibilities to increase their know-how in addition to getting their salaries.

Typically, a success of a company is only considered from the perspective of owners, but good profits and well running business is often a result of fulfillment of customers' and employees' expectations.

Highly motivated employees are willing to give more of themselves to the company and they are more efficient than employees that lack motivation. Efficiency and motivation of company's employees reflect directly to customers and eventually have a great impact on a company's profit margins in the long run. If all three stakeholders are pleased, it triggers this flow of good, which is demonstrated in the picture below. (Hannus, 1993, s.72)

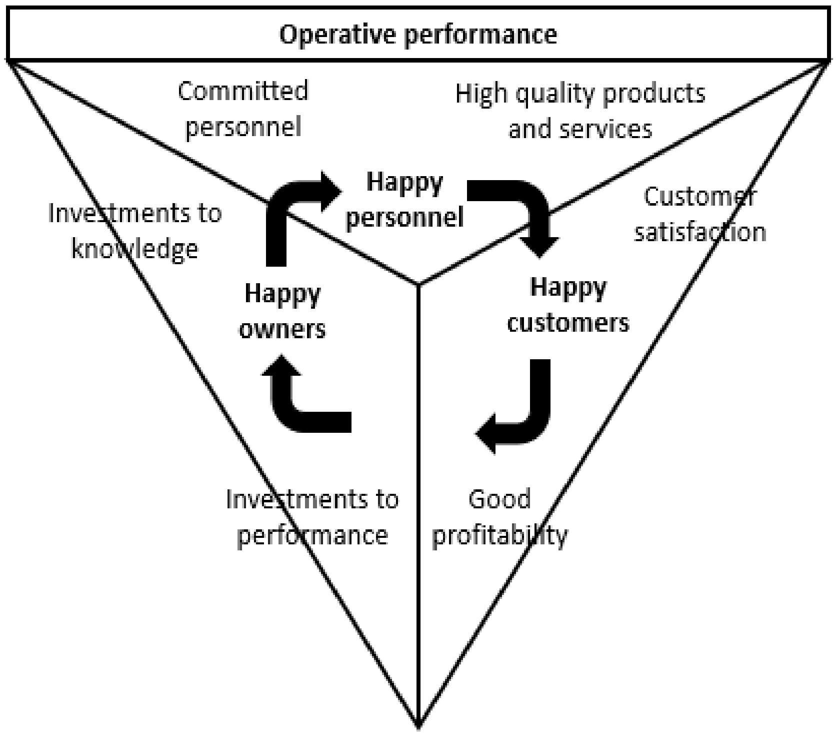


Figure 3. Flow of good (Hannus, 1993, s.72)

Production performance can be measured in different ways. Often companies follow several key performance indicators (KPI), that can measure operative performance or financial performance. An example of typical financial KPI could be revenue per month, which tells management how business is running from a revenue perspective. In production operative performance is often interesting, as it can tell how production is running in terms of finished orders or production lead time.

Productivity is measured by the utilization of resources, like labor or material. For example, one basic formula to define productivity is units produced per labor hour worked. There is a strong link between productivity, quality, and profitability, hence it is often a priority in a production environment. On a larger scale productivity is often energized by competition, which results in better productivity and reflects to customers as better value. (Anil Kumar & Surehs, 2009, s. 18)

Productivity can be improved by either improving processes, controlling inputs or deploying new technology.

To understand how to measure operative performance, it is required to know what factors of performance are under the scope. Examples of factors of performance are quality, delivery lead time to customers, internal lead time, cost and waste. Only after deciding proper factors of performance, it is possible to define ways to measure them. Hannus (1993, s. 90) has listed some examples of operative KPIs in his book Prosessijohtaminen, and these are listed in the following picture.

Factor of performance	KPI
Quality	Rate of successful delivery of products
	Number of complaints
Delivery lead time	Delivery lead time
	On time deliveries versus all deliveries
	Damaged deliveries versus all deliveries
Production lead time	Set times of production machines
	Production lead time
Cost and waste	Amount of waste in production per produced unit

Table 1. KPI Examples

There are different approaches towards measuring performance with the help of mathematical formulas. Often flow time is one key performance in manufacturing. There are simple formulas to calculate e.g. minimum, maximum and mean flow times for manufacturing processes. Depending on the industry, also the number of tardy jobs could be an important factor of production performance.

Some performance measurements are purely used for manufacturing to help scheduling of orders. Shortest processing time (SPT) rule, weighted shortest processing time (WSPT) or earliest due date (EDD) are basic examples of these. Also flow shop scheduling, Campbell, Dudek and Smith heuristic approach and Johnson's approach are used, but they are often used in more complex situations and require more detailed information. In this study SPT, ESPT and EDD approaches are explained more detail.

The shortest processing time (SPT) rule minimizes the time spent by jobs in the system, thus minimizes the mean flow time of the production. This will help to manage rapid turnaround time and help reduce in-process inventory. In practice this means that jobs that have the shortest lead time will be produced first, continued by the next shortest product. An illustration of this can be seen in the following. (Anil Kumar & Surehs, 2009, s.239)

Sample of orders

Job number (j)	1	2	3	4	5
Processing time (t)	13	2	5	9	8

Production sequence by SPT rule

Job number (j)	2	3	5	4	1
Processing time (t)	2	5	8	9	13

Table 2. Production sequence with SPT

The weighted shortest processing time (WSPT) rule is based on the same idea, but it also considers the importance of each job. Processing time is divided by the weight, which indicates the importance of the job. Jobs with greater weights are considered more important than jobs with smaller weight. (Anil Kumar & Surehs, 2009, s.240)

Sample of orders

Job (j)	1	2	3	4	5
Processing time (t)	13	2	5	9	8
Weight (w)	1	2	1	2	3

Production sequence by WSPT rule

Job (j)	2	5	4	3	1
Processing time (t)	2	8	9	5	13
Weight (w)	2	3	2	1	1
t/w	1	2,67	4,5	5	13

Table 3. Production sequence with WSPT

The earliest due date (EDD) rule maximizes job lateness and minimizes job tardiness. The lateness of a job is the difference between the completion time and the due date and it can be positive or negative. Tardiness is measured by comparing the completion date versus the due date. If the job is completed after its due date, it is defined as a tardy job. (Anil Kumar & Surehs, 2009, s.240)

In EDD sequencing jobs are arranged based on their due date, so that the job of which due date is first, is also produced first. The completion date is then compared with the due date, and if the value is negative, a job is completed on time and is defined as non-tardy. However, if the value is positive, it means that completion is late from a due date and is defined as a tardy job.

Sample of orders

Job (j)	1	2	3	4	5	6
Processing time (t)	10	8	8	7	12	15
Due date (d)	15	10	12	11	18	25

Production sequence by EDD rule

Job (j) (EDD sequence)	2	4	3	1	5	6
Processing time (t)	8	7	8	10	12	15
Completion time (C)	8	15	23	33	45	60
Due date (d)	10	11	12	15	18	25
Lateness (L)	-2	4	11	18	27	35

Table 4. Production sequence with EDD

These different approaches are each suitable for different purposes. When these decisions are made, it is important to understand the company's working environments and effect of production in the supply chain. For example, in some cases it might be beneficial to serve specific clients with extra efforts and make sure that their jobs are completed on time.

3 METHODS

This research will be conducted as an empirical case study. The data used is collected from observations, interviews, and data analysis. The data gathered from observations and interviews are analyzed and generated into current state analysis. The study is focused on real life problems and actual order and production processes operated in a business.

The research problem is normative, meaning that the purpose of this study is to find out how things should be in the future, instead of thinking of current situation.

3.1 Process observations

Currently procedures in order and production management are not defined with sufficient specificity. The ways of working have been evolved during the time, which has eventually led to the current situation where processes are not clear to all involved parties.

Order process lacks control, especially in wooden products. Commonly wooden products have been considered too special to fit in to any precisely defined order process, and therefore it has been separated from other controlling activities. However, this leads to a situation where both a carpenter and a customer have somewhat unclear view of production.

Also, a general overview of production is weak. The carpenter might know what he is going to do in next days or weeks, but if there are any changes, it is harder to react to them. For example, if the carpenter gets suddenly sick, there is no other people to know what the status of upcoming jobs is.

All these extra jobs are also making it difficult for the carpenter to concentrate on his main task when several people interrupt him occasionally by telling or asking something or by delivering new work instructions for upcoming jobs.

On the contrary, the process for metal products is a more controlled. In metal products orders are controlled by a specific person, who is responsible for having a better understanding of production and communication towards clients. Customers know that they should contact this person in all questions or information about cases they have.

From customer perspective overall order process is not clear. In ideal situation, they would have only one channel which would handle all orders, no matter what kind of a product it is. Most likely this would also improve the work of production, as they could rely on that someone has a bright overview of all jobs and they could just work according to instructions, without interruptions from customers.

3.2 Data analysis

Orders of metal products have been documented with a simple excel sheet starting from late 2019, so it is possible to analyze orders and order quantities for them. However, the data is not complete, as the collection method and input fields have been evolved during the time. For that reason, this study only uses data from March 2020 to September 2021, as this period has been more static. Total sample size is 506 orders, of which lot sizes vary from a single product to dozens of elements.

The order follow-up sheet consists of overall information about ongoing and past metal workshop orders. Collected data is separated to different columns:

- Status of the job
- Date of order
- Product type
- Project information (project number and name)

- Customer information (name and location)
- Amount of ordered elements / parts
- Extra information (free text)
- Required production steps (cutting, machining, assembly)
- Inbound raw material (aluminum profiles, glass, other) and their arrival dates
- Due date of customer
- Actual order completion date

From this order data it is possible to categorize orders by different product types and required product steps. It is also possible to analyze order and completion volumes, and flow times of different products.

There are five different main aluminum products that are manufactured in the metal workshop. Because specific details of sold products are a business secrets for the company, in this study these five products have been separated in the statistics and are represented individually as products A-E. Rest, rarely manufactured, products are all combined into product type “other”, because their individual shares would be so slim. In the following chart each product’s shares of all orders during observed period are illustrated.

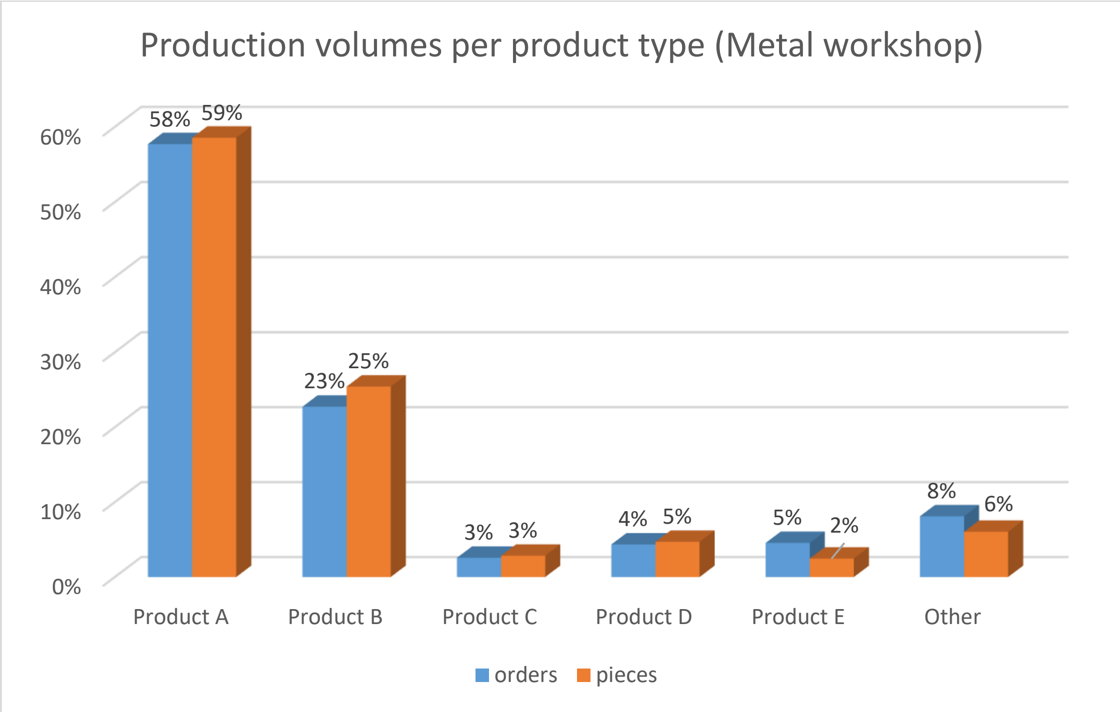


Figure 4. Production volumes per product type

The chart indicates that product A and product B are generating 81% of total orders, and 84% of all produced goods. From both, order and manufacturing points of view, the company should especially focus on their order and production process to these two types, to make their production as efficient as possible.

A crucial part of metal production is assembly, as normally all main products that are manufactured in the metal workshop require some sort of assembly. Exceptions to this are products A and B, that are sometimes sent to worksite in part, and assembled there. For product A factory assembly rate is 82%, and for product B it is 97% while products C, D and E are assembled in the factory prior delivery in all cases. However, in ideal situation also all A and B products would be assembled during the production process, instead of doing assembly in changing environments somewhere else.

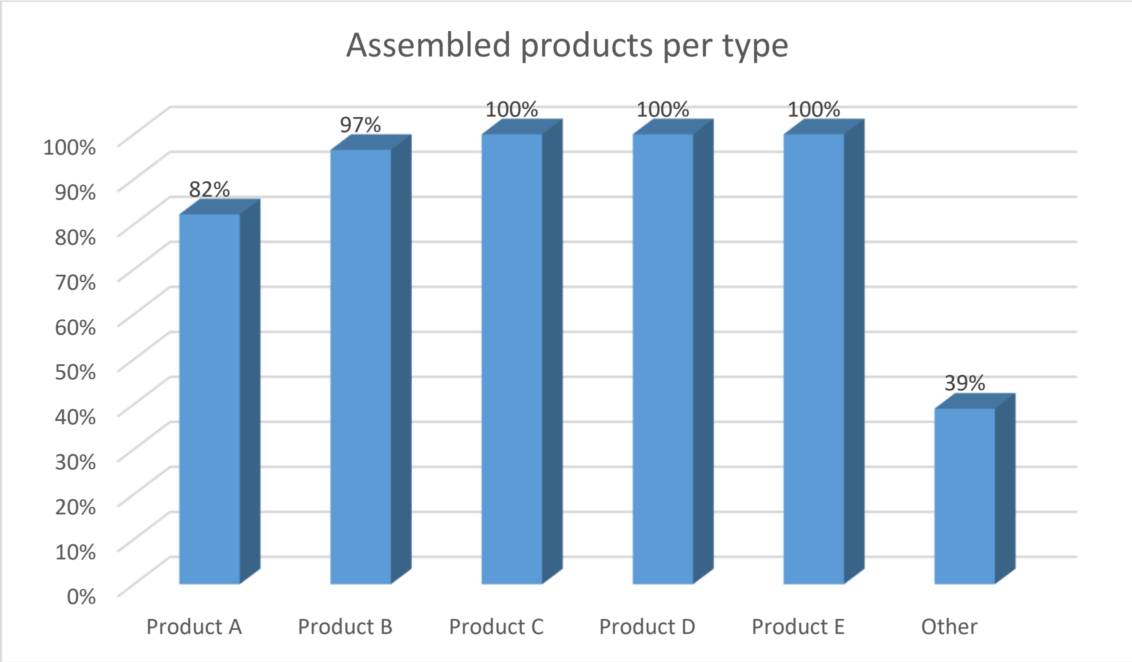


Figure 5. Assembled products per type

Study of order timings examines how many weeks before due dates orders are delivered to production. More than half of all production orders are sent to production at least five weeks prior due date. These orders are ideal jobs from production point of view because there is enough time for production to work according to a normal working queue.

Orders that are sent three or four weeks prior due date form one third of all orders. In normal situation these are considered fast, but still relatively feasible jobs, which should not cause bigger issues.

The biggest challenge in production is orders that arrive only one or two weeks before they should already be completed. Their share is slightly more than 7 percent of all orders. Urgent jobs are more likely to be tardy, as one- or two-weeks timing is not always enough for production. Even though theoretically it would be possible to complete them on time, it would require a re-scheduling of other jobs, effecting on their completion. In a worst-case scenario, if their workload is already high, one extra job at the beginning could lead to failures in many later jobs, that are likely to been agreed weeks before.

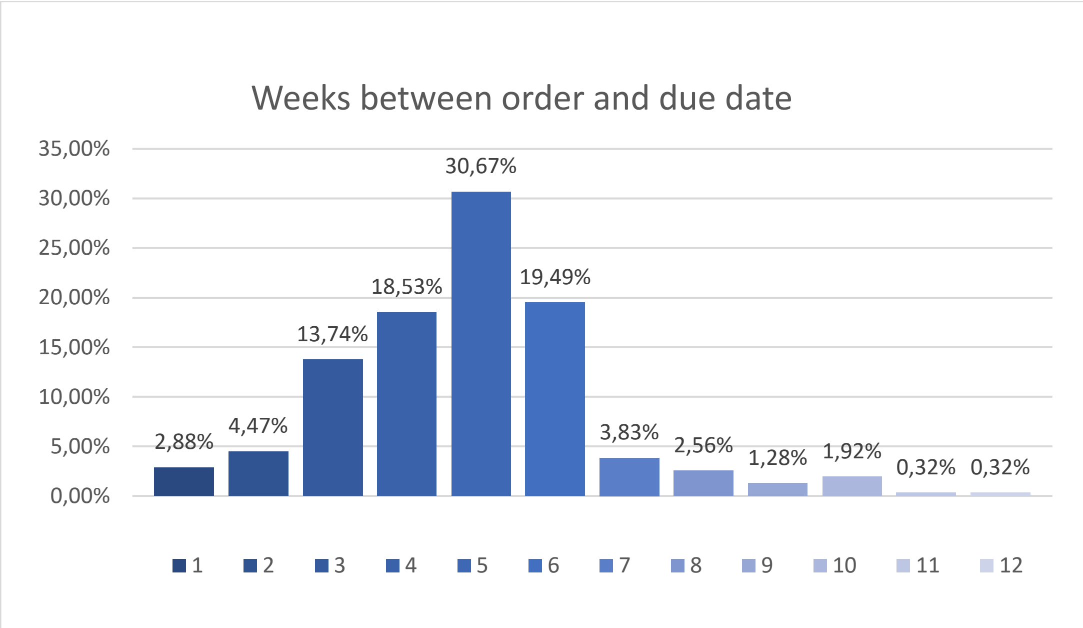


Figure 6. Distribution of weeks between order and due date

If the same data is compared between the order date and the actual completion date, it is possible to see how fast orders have finished during the given period. 42 percent of all orders are completed five or more weeks after order, while almost half of all orders have been completed three or four weeks after order has been received. 12 percent of all orders are produced as urgent jobs.

What can be seen from these numbers? By comparing the distribution of these two charts, we can see that they have similar symmetric shape. However, completion date distribution is slightly more skewed left than due date distribution. Also, cumulative shares of each week’s distribution is bigger on completion distribution than due date one. From this perspective it could be thought that there have not been any tardy jobs during the period.

However, statistics tell that total of 36 orders have been late during the period. When sample size is 506, tardiness rate is 7.11%. This means that some jobs have been completed considerably earlier than their due date is, and some orders have been late. When all these orders have been put into the same calculation, their average goes on a positive side. The conclusion to be drawn from this is that there should be some great possibilities to improve scheduling to meet the requirements of orders, and reduce tardiness rate, if the process around them is working as it should.

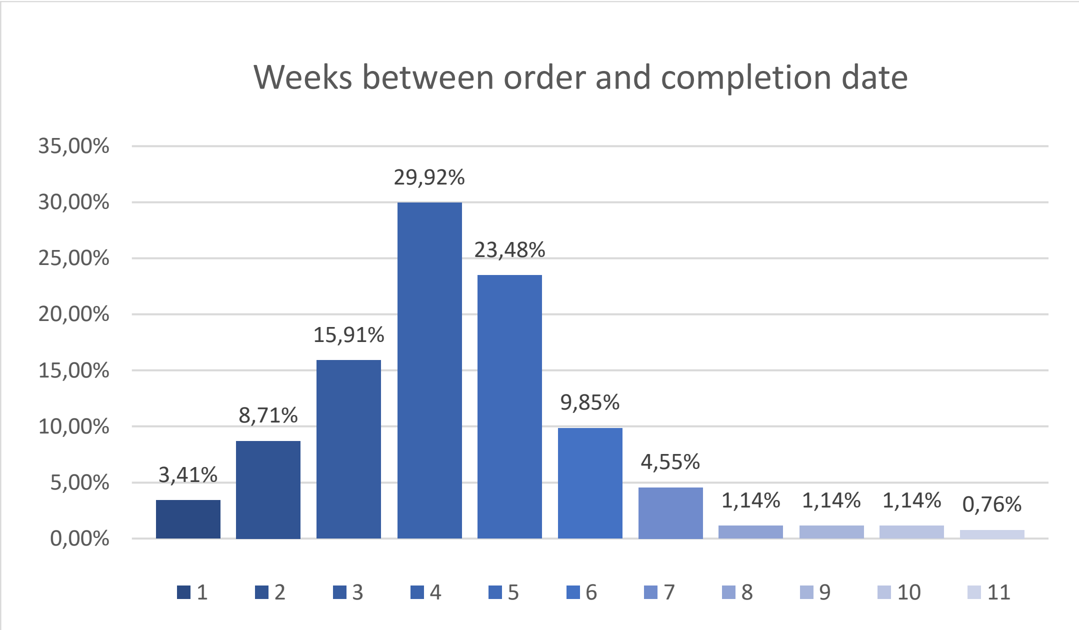


Figure 7. Distribution of weeks between order and completion

For wooden products there is no long-term historical production data available about piece or order volumes. Therefore, it is not possible to statistically analyze how product distribution would look like on that side of the process. All demand estimations are based on general information, discussions, and observations.

There are three main products, which are produced regularly. In addition to them, there are countless special products that are produced once or a couple of times. Production order for wooden products is currently sent via email or delivered directly on paper to the carpenter. In the current system, there is no order platform for orders, so each order is different.

Production volumes on wooden products are significantly lower than in metal products, but often they are more complicated with more production phases and require more manufacturing time per product. Also, as stated, many products are often unique and produced only once. This leads to a situation where it would be challenging to have a common order tool for all the products.

3.3 Interviews

Interviews for the study were conducted to specific people who are working on production and order management. Because the purpose of the interviews was getting a better understanding about the problems and limitations of the current system, and there was no right or wrong answer to questions, it was conducted as semi-structured and open-ended interview. In a semi-structured interview, the framework of questions is prepared before the interview, but questions are explored in more detail during the conversation, depending on answers.

Interviewees were selected among people who are working with production orders on their normal work. Thus, the main order management person and workers from wood and aluminum production were defined as suitable interviewees. The framework of questions for the interview was following, but there were extra questions for each participant.

- How does order management and production control affect your job?
- How satisfied or dissatisfied are you with the order process overall?
- If dissatisfied, what changes in current style would help with these issues?
- What kinds of questions or difficulties have you had regarding production orders in the past? Where did they arise from?

- What worked well for you?
- What would you want to change about production orders?
- What order information you need in your work?

The overall results of the interview support the result of observations. The respondents expressed their dissatisfaction towards lack of a clear system in order management.

Especially in wood production the number of different orders and their control was seen as a problem that complicate efficient working, because there are many different channels and ways to do them. It is also hard to evaluate schedules of tasks because some people try to override the existing production plan with their orders that should be handled with higher priority than others. This issue is not only with production orders, but in general management of production.

Based on observations and interviews gathered from the company, a minimum level for order information is defined. A good order contains all the information that is required throughout the whole process from order to product delivery. In the ideal world, there should not be a need to ask any clarifications related incoming order or production process. In that perspective, a good order would have at least following information:

- Product information
  - Product type
  - Materials
  - Dimensions
  - Surface treatment
  - External attachments (if needed)
- Project information
  - Project number and name
- Inbound raw material information

  - Arrival date
  - Use of materials
- Due date for the order

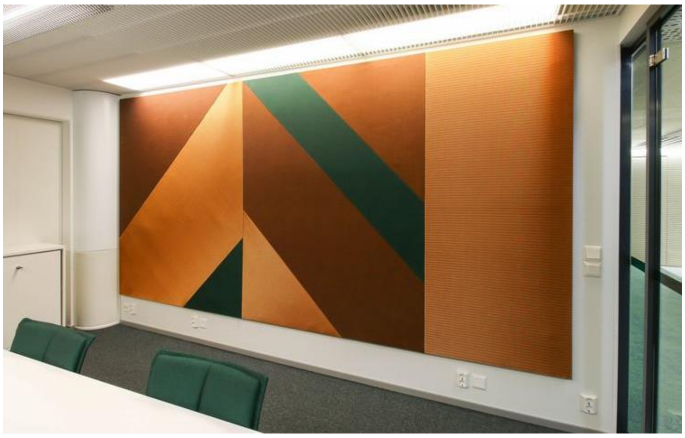
When this information is communicated accurately to order control, they can validate the order, determine and define required production tools and methods, control production process and schedule production so that every order will be completed on time.

4 CURRENT STATE ANALYSIS

4.1 Products and production unit

Inlook produces a lot of different products in their production unit in Helsinki. Based on production volumes, the majority of production orders are Inlook's own brand partition wall products, elements made of aluminum profiles and glass. Minor part of orders is products that are built from wood instead of aluminum. Despite smaller volumes, these wood products are critical for the business, because they tend to be special solutions that are not possible or reasonable to purchase elsewhere.

There are 5 main aluminum partition wall product types that are produced regularly, on a weekly basis. In addition to them, there are a few aluminum products that are not high-volume products, but which are occasionally produced. Wooden products are more unique and have higher variety of different sizes and types. The last category is very special products that are produced once or a couple of times, and these can be basically anything made of wood or aluminum.



Picture 1. Examples of products

Most of the time there are 3-5 employees working in production, one or two carpenters, one or two metal workers and one or two assemblers. Each of them has their own areas of responsibilities but can change from a task to another smoothly depending on work requirements. Workshops and the machines in use are modern and in good shape in all places, and each workshop have access to a computer that is connected to network.

All production orders are received from company's internal customers and project managers, so there is no production that would be sold directly outside of the company from production organization. It is an advantage in communication, as it is possible to communicate easily and openly to all current and potential customers, as they are the company’s own employees. This is an advantage also from a change management perspective, as the customer base is limited to certain people, which makes it easier to control the order process and make changes to it if needed.

However, this can also be a disadvantage, because there is no possibility to influence on the customer base. This means that the production market is fixed.

4.2 Order process

The order acquisition phase starts from an external customer’s order, who decides what type of a product is desired to buy. The external customer in this case is referred to “client”. A client communicates their vision to the company, and at this point the order process shifts to Inlook internal process. In this process, a named project manager from Inlook’s side is the contact for both, client, and production unit, about order and its requirements.

Every project is different, and for that reason each product needs to be customized to fit into the current place. The basic idea in all solutions is the same, but there are always bigger or smaller changes in product types, sizes, colors or installation procedures, which makes each order unique.

When the project manager has received all the required product information from the client, the project manager starts planning how the desired product will be actualized in the specific case. Project manager measures the dimensions of the place and adjusts the exact size of the product, defines required materials, resources, and plans schedule for the installation. Then the project manager creates orders and material lists all required material for the project. Some materials are collected directly from Inlook’s warehouse, some are ordered from third party vendor. When everything is planned, project manager communicates the order to the manufacturing department.

At this point order is split to different lanes based on production type, depending on the main material type.

Aluminum product orders are sent according to agreed process via email to the person who will validate the production instructions and delivers them to production by printing them out to paper. Orders are also updated to the shared follow-up excel that is used to control workload. With this procedure the company tries to ensure that production orders have all the needed information with a clear and accurate way, and make sure that production is controlled, and the status of each work stays updated.

Once the instructions have been delivered to the production, they have all information to start working, and order move over to the order fulfillment phase. Employees follow the job order of the workload sheet, which is also serving as a work queue. After each step of each job, they update job status to the workload sheet, and when the job is completely done, they send a confirmation email to the person who has ordered this job, informing that the job is ready for pickup or delivery.

For wooden products there is no similar control, as these orders are delivered directly to production. Some project managers send them via email, some use paper sheets and some just give spoken instructions. This leads to a situation where overall order control is lost and only the employee who is doing these jobs knows what he is supposed to do. Sometimes this results in a forgotten task or excessive workload, especially during holiday seasons or other absence.

In the following picture these main steps and differences of aluminum and wood products production flow are visualized.

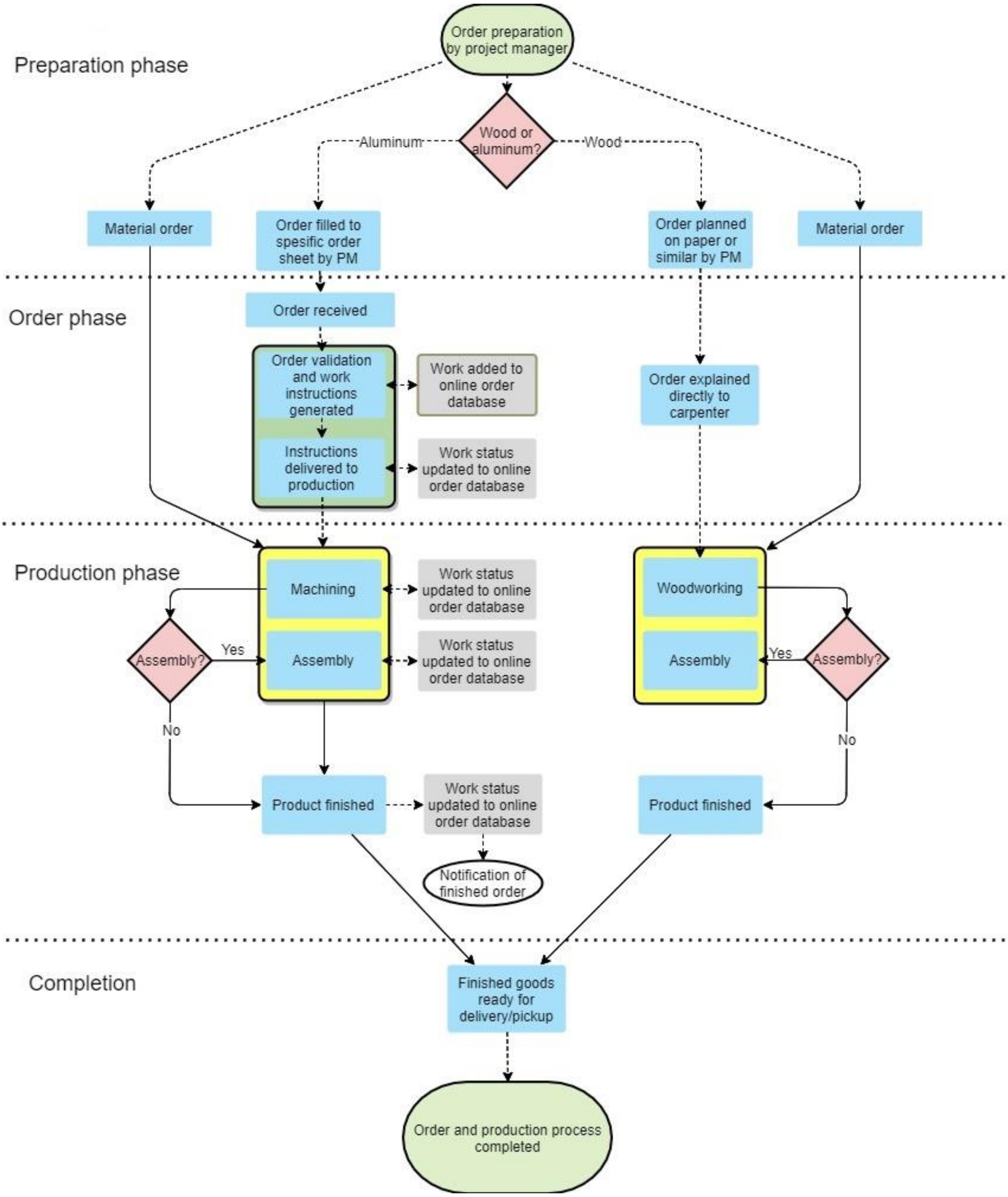


Figure 8. Current process flow of basic wood and aluminum products

4.3 Production process

The company has two main workshops, one for wood products and other for metal products. In addition to them, there is also an assembly station where most metal products and some wooden products are assembled prior to delivery. Logistics function is supporting all these three stages, by providing services to production especially at the beginning when raw materials arrive and at the end by controlling the dispatch of completed orders.

Management of production in all these phases is weakly connected to each other. There is a historical reason for that, as in the past different stations were operated by separate companies. In the past wood production operation was directly in Inlook's control, but machinery and assembly of metal products was operated by a subsidiary, who had their own management and style of doing things.

When these operations were combined under one company and organization in 2020, ways of working still stayed the same, even though they share the same management. For example, orders for the metal workshop and assembly are controlled by an order management person, whose responsibility is to prepare proper work instructions and control workload, while the process for wood production is completely missing this phase.

This means that no one have a clear idea of the overall workload of all production stations. This makes it hard for the management to control the overall situation and workloads of individual people. In addition to that, the lack of any documented production orders leads to situation where there is no documented data about production history, that could support decision making and planning for example during holiday times.

If all the orders would be controlled under the same process, it would standardize order process and release production workers' time for production instead of receiving and controlling orders. Also, there is a demand for a collective order platform, which would make sure that all orders have required order information for each case. This platform would also help management to oversee the overall situation of each station to make sure that every order is completed on time.

Follow-up of production is limited to tracking completion versus a due date. In the end that is the most important indicator of performance on a general level but does not provide much information about how the production process could be developed. If the process would be divided into smaller subparts, such as production times per phase, it would enable management to follow how these smaller parts are working. By this approach, process bottlenecks are easier to recognize.

When bottlenecks are recognized, their improvement is possible. If some part of the process is slower than other, process changes, new tools or human resource management could improve the situation. The better flowing production process, the better is the outcome.

During the interviews and discussions with company representatives, some things were raised above others regarding production output. In this type of production, the most important factors of performance are quality, delivery lead time and cost.

Quality is both time-sensitive and material sensitive, including the rate of successful delivery of products and product quality. In practice this means that products should be completed on time and tolerance for quality defects is zero. However, this should be done with a cost-sensitive way. The amount of waste per product should be as low as possible, including the waste of materials and waste of working hours.

None of these indicators are currently monitored in the production management, other than just a general level. The current process or tools do not provide any data for automatic process follow-up, so first the data should be somehow collected for required production parts. If the data would be collected, it would be possible to management to run reports about performance. KPI’s would indicate overall performance in selected factors, which would be easy to check and communicate on a daily basis. Then, if the level of performance drops, management could dig deeper into the number to find a reason for the drop.

5 RESULTS

5.1 Order process and material flow

The production method is not something that a company can choose, but it is determined by the specifications of product and production models. End products that are under the scope in this study start with unique order, even though product types are similar to each other. One order usually consists of multiple similar products, that are then manufactured according to order. When the product is produced according to customer order, it is defined as order-based production.

This also means that the signal for the order is generated from a need. If there is no need for a product, they will not be produced. This type of method is called pull production. Typical order consists of multiple items, so they are done in batch mode, instead of making single product or repetitive production. In batch production planning and control are increasingly important.

Currently the order process is unorganized. There are different channels for orders and each project manager has their own habits and ways of doing orders, based on the experience they have. Some of them prepare exact written instructions with good pictures, but some of them prefer spoken instructions directly to employees. This leads to uncertainty between production workers and management, as it is hard to control the workload of different people if there is no information about all ordered jobs.

Different product types have different approaches in the current order process. The order process of metal products is more advanced than wooden ones. That is found challenging because customers of different product types are the same, and at some point, they have all similar processes.

One basic problem with the current procedure is that there is no unambiguous order platform. Each product type is handled differently, which makes it hard for the client and the order handler. According to Huffman & Kahn (1998), a typical risk of order acquisition is a possibility of communication errors between a customer and a producer, eventually leading to a situation where they order something that is not intended or possible.

This challenge would be tackled by having an order platform that would help collecting required information regarding the order, and limit orders to only those that are possible or desired by the producer. In ideal solution this platform could be a program, that would be integrated or at least communicate with company's ERP system, to provide real time information about production, material resources and upcoming orders.

Building a proper system that is integrated into other systems in the company is not a small project, even if there would be somewhat suitable solution available in the market. Those platforms are also often relatively expensive for purposes where production is not the main business for the company and production volume is not very high.

If ERP-integrated MES system solution is too expensive compared with its benefits, there are other ways to do it cheaper and with immediate effect. First step could be a standardized order sheet with the use of other available software, e.g. Microsoft Office, that would have all the required fields, that customer should fulfill before sending order. If it is filled with a computer, it could have a built-in system for checking that all the required information that is needed.

Based on the requirements of order and production control, there are a few mandatory fields for placing successful order:

- Client information
- Product information
    - Measures
    - Color
    - Other
- Material information

    - Required warehouse items
    - Material from external sources and their schedule
- Due date

However, even if there would be a platform for orders, it would be hard to cover all product types. Most likely it would only cover those products that are often produced and left out all special orders that are produced once or a couple of times. For them it is harder to define mandatory information because their requirements can vary.

A suggestion in this situation is that there would be exact individual order sheets for regular products that are produced often and one general sheet for other products. This general sheet would have all general data, such as work information and due dates, but not on a too detailed level, so that it could be used for different product types.

Another critical issue is to clarify ordering channels. It would be preferable to have a clear channel for all production orders, no matter what type of product it is. If this is not built-in to the ecosystem of the platform, in a basic version it can be just a shared email address, where all the orders would be sent. By this approach, incoming orders would be visible to all required people in the organization, even if there are any absences or other exceptional situations.

This major change compared with the current system would be a centralized order receiver. All orders would be generated in the same way and a defined order controller would process them according to instruction. This would clarify the process and provide a more efficient production process, as all the information would be controlled by the same person. Also, production workers' resources could be directed to efficient production instead of handling and planning orders.

All material that is required during the production should be also stated during this order fulfillment phase. Currently, the majority of materials are items that are stored in Inlook's own warehouse, which means that they are controlled in the company's ERP system. While creating the order, the client should indicate item requirements for the order in ERP and send a picking list of items with the order. With this approach, production knows to collect all items from the warehouse prior to production.

For materials that are coming from external vendors, the client should indicate a date when these materials arrive at production. If this information is not available, it is impossible to plan and schedule orders accurately.

When all required information is gathered to order, its handler would validate information and add them to a shared work database that could locate in the company's shared environment. This database would be visible in management and in production and it would form a task list for all upcoming jobs. Production could follow the given order from their computer and update job statuses directly to the database. Detailed work instructions would be sent to the production electrically.

The improved order process and its stages are explained in the following process chart.

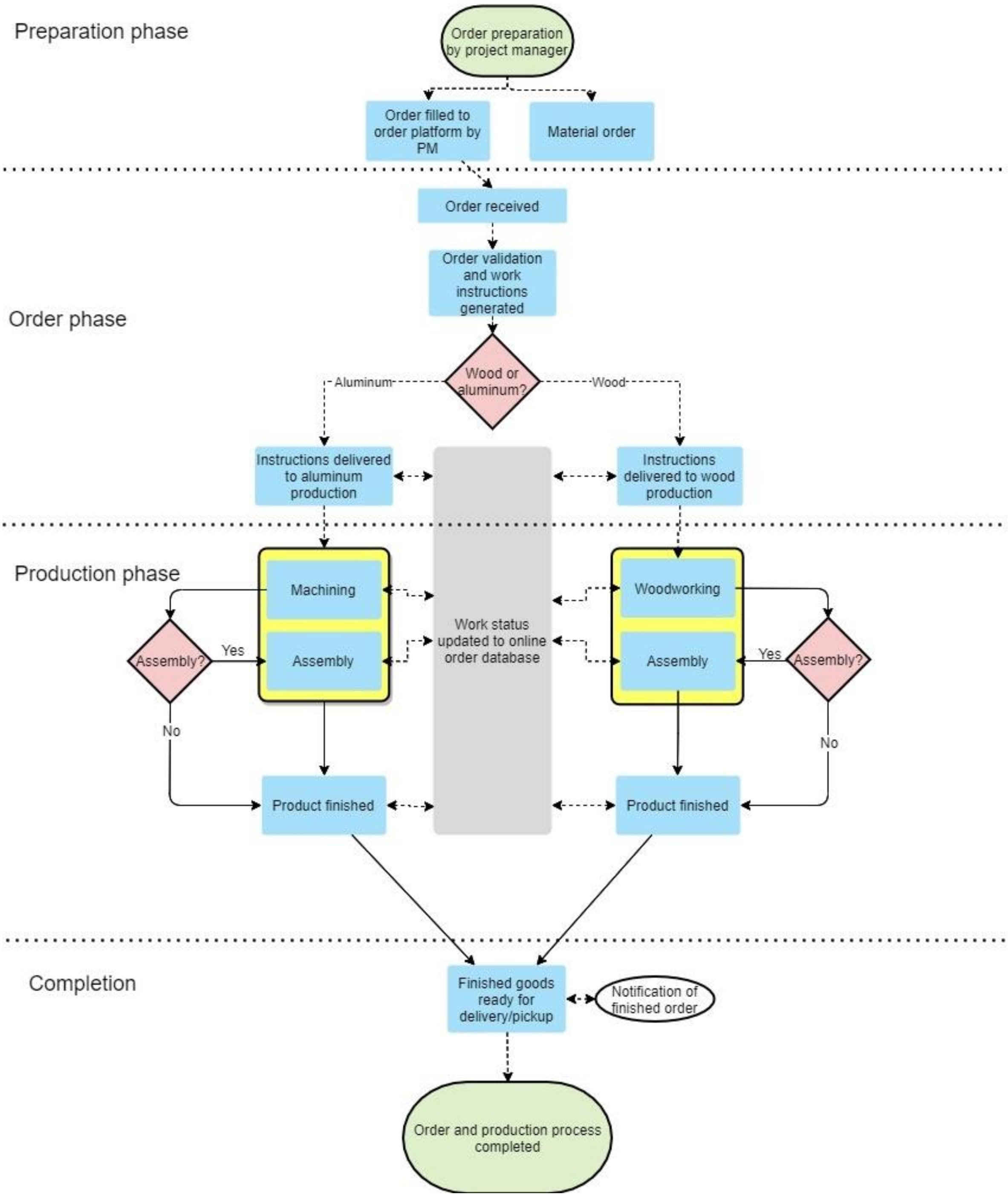


Figure 9. Improved order process flow of basic wood and aluminum products

5.2 Planning and scheduling

Products in the scope of this study are all unique products that are produced for an individual project. They are normally ordered from three to six weeks before they need to be ready, and therefore their due dates are already known when order is placed. Therefore, in this case production is suitable to apply earlies due date (EDD) rule.

When EDD is applied, orders are planned in due date order. This means that orders with the earliest due date are produced first. The challenge in this system is its fairness regarding orders that have been done early if an order that have been done late will be produced first. This is not a problem if both jobs are completed on time, but it the production of later order will compromise the first one's completion, things get tricky.

Another issue that can affect EDD production is the availability of materials. Logically, if the materials of production are not available when production should start, proceeding is not possible.

EDD production's benefit compared with SPT or WSPT production is its better impact on completion dates, thus helping with a tardiness rate. With SPT tai WSPT production method production lead times would be faster, but its direct impact on success of projects is lower. In many cases completing orders days or weeks before the due date would not help the project at all compared with a situation where a product would be completed just in time for a due date.

For this reason, the company should follow EDD rule in their production with some restrictions. To be placed according to the due date, the order should arrive at least three weeks before the due date. Another restriction is that materials should be available at latest two weeks before the due date. These restrictions will give enough time for production to adjust its schedule and have a great possibility to have orders completed on time.

According to historical data analysis, this would cut off approximately 7 percent of all orders. For these 7 percent of the orders due date should be moved forward, so that it is at least three weeks from placing the order. This would then be communicated to customers, whose responsibility is to adjust their requirements according to that. After this due date adjustment, the order would be placed along with other jobs in the schedule.

By this method, customers will likely focus more on their orders, as they realize that late orders will also be completed late. In business-critical situations, and if there is a possibility to give up without compromising other jobs, it would be possible to be flexible with this rule.

5.3 Production process and performance

The current way does not support management with exact knowledge about production at its different stages or on a detailed level, as there is no required data available. This leads to difficulties for managing production in the best possible way and getting out efficiency that would be possible. With the help of data and statistics, it would be easier for management to maintain high performance level on quality and efficiency, than just observing processes.

Thus, it would be highly recommended to create a proper performance indicator, that would be clear and indicate how production is running in terms of quality. These high-level KPIs would indicate if things are not working the way they should be and allow to start actions that would fix the situation.

As quality and cost-efficiency are important factors for the company, these KPIs should cover these topics. Some possible KPIs that cover these important factors are listed in the following list:

- Rate of successful delivery of products
- On-time deliveries versus all deliveries

- Amount of waste in production per produced unit
- Paid working hours per product per type

All of these are simple but efficient KPIs that are easy to follow. Also, difficulties in production immediately reflect in these.

In addition to them, production could have its own KPI’s that would go into details of production. These could be for example production lead time per product or set times of different production machines.

6 CONCLUSIONS

The purpose of this thesis was to understand the most important elements of efficient and high-quality order management and production control and recognize challenges in the case company's production order control and production management reflected on that research. The research was limited to specific products and only to their main production unit in Helsinki.

At the beginning, the major points of order management and production were researched from literature and other sources. Production types, production planning and scheduling were defined for this case. This worked as a benchmark for the flow of an ideal process and the findings of this phase were later compared to the case company's process. Also observations, data analysis and interviews were conducted to understand the challenges of the current state in the case company better. All this was summed up in the current state analysis.

The research found out some main parts that are affecting to order and production process negatively. The most important one was the consistency of the order process. The order process was an outcome of different historical changes in the organization, and it was changing depending on who has made the order and who eventually will complete the order.

Another major improvement finding was related to planning and measuring production. A continuous measuring of production in the company was almost non-existing, which led to a situation where management is not capable of measuring the performance of the production, neither in quality nor efficiency point of view. Also, other smaller places of improvement were recognized, such as communication problems.

The situation could be improved by re-organizing the order process. There should be a centralized order channel for all orders, which would improve the clarity and visibility of the process. This would also improve the managements control of the production and reduce the amount of extra work related to order handling from production workers. Also, it would be recommended to have a better controlling platform for orders, which could be accessible from all places and have real time information about progress of the production.

On the overall level this research was completed as it was planned. The thesis answered the research question and fulfilled all objects that were set up for it before the research started, and therefore the result is successful.

This research was only focused on one production unit, which means that in the future research of this topic could be broadened to other production units as well, or even the overall research of more strategic perspective; how and where these products should be produced. Also, this specific topic could be researched on more detailed level, especially about production part of the study.

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