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Improving product flows in order to reduce order-to-delivery lead times

Master of Science Thesis

GUSTAV MÜNSTER
ULRIKA VESTIN

Department of Technology Management and Economics
Division of Logistics and transportation
CHALMERS UNIVERSITY OF TECHNOLOGY
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Technical report no E2012:0088
Department of Technology Management and Economics
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone + 46 (0)31-772 1000

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Abstract

Within Company 1 there is a unit, with license for special environments, called Unit 1. Unit 1 is globally responsible for the business and product development of Product 1, 2 and 3. In the master thesis, the work is delimitated to cover the situation for the production site of Unit 1, which is situated at Location A. Included in the supply flow for Unit 1 are also Company 2, a producing facility at Location G, and Supplier 1.

The master thesis seeks to improve the product flows for Product 1, 2 and 3. The purpose of the improvements is to better meet customer needs, regarding order-to-delivery lead times, in order to enable increased sales. The purpose is obtained by eliminating waste and increasing the capacity in the three product flows.

Unit 1 apprehends difficulties in binding potential customers, due to the length of lead times for products made to order. Unit 1 supplies products to Original Equipment Manufacturers (OEMs) who demand even and reliable lead times, and aftermarket customers (AMC) who demand short lead times. The product range for Product 1 and 3 is wide, making the customer demand difficult to foresee. To meet the needs of the different customers, the product delivery strategies at Unit 1 are both make-to-stock and make-to-order.

With reduced lead times from customer order to delivery, Unit 1 expects to grow primarily on the aftermarket, where short lead times are utterly important. By investigating and analyzing the current process flows, Unit 1 believes that non-value adding activities can be identified and eliminated, leading to reduced lead times.

The study was initiated by investigating the customer needs, to give an indication of the length of the lead times accepted by the customers. The information gathered was compared to the lead times found during the chartings of the current flows of material and information. The findings were used as a basis when analyzing the current state and suggesting improvements for the future product flows. The information was gathered at Unit 1 through interviews, sales statistics documentation and production observations, along with literature studies, and value stream maps were used to visualize the bottlenecks and sources of waste in the product flows.

The study showed that there are three categories of customer needs, with differing demands on lead times: non-urgent needs, urgent needs, and needs arising when newly interested in testing a product.

The two latter needs are currently fulfilled by having a make-to-stock strategy. The improvement proposals presented provide the required conditions for fulfilling both the non-urgent needs and needs of new interests with both the make-to-stock and make-to-order production for all three products.

The improvements presented are developed to serve both a long term and a short term purpose. Some of the improvements can be implemented without further investigations, whereas other improvements require additional research and allocation of resources to the implementation phase. For certain suggestions there is an implementation order enclosed, to ensure that the required prerequisites are established when implementing the improvements.

KEY WORDS: Lead time reduction, Waste Elimination, Process Improvements, Value Stream Mapping.

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Gustav Münster and Ulrika Vestin
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Terminology

AMC: Aftermarket Customer; using products in production equipment.
Basic product: A product designation from which a final Product 1 or Product 3 is made through different modification processes.
CL: Abbreviation for Centrallagret, equal to Location A
IDWs: Company 1's Intermediate Distribution Warehouses are located at each of Company 1's factories for refilling Location B and supplying OEMs, large AMCs and Unit 1. The IDWs that are supplying Unit 1 are located at Location A, Location C, Location D, Location E and Location F.
Location B: Company 1's Distribution Centre at Location B, which is the regional warehouse which directly, or indirectly via Distributors, supplies Company 1's AMCs at Location A, as well as and Unit 1.
OEM: Original Equipment Manufacturer; using products as components in their manufacturing business, but also in their production equipment.
Product 1, Product 2, Product 3: Three product families, each consisting of different final product designations.
Product designation: A final finished goods product, with different dimensions, seals, shields, clearances etc.
Product flow: the common process flow of material and information for each of the three products and its designations.
RFP: Ready for picking; received products are registered by a warehouse as available in the system.

1. Introduction

This introduction chapter describes the conditions of the master thesis project work. It answers the question why the project is conducted, what it shall achieve and within which frameworks. It starts with a background description to the thesis, continuous with a problem description to why the thesis is conducted and leads into what the purpose and objectives are. Finally the scope is stated describing the framework of the thesis project.

1.1. Background

Within Company 2, there is a unit with license for special environments, called Unit 1. Unit 1 is globally responsible for the business and product development of Product 1, 2 and 3. In the master thesis, the work is delimitated to cover the situation for the production site of Unit 1 situated at Location A. Included in the supply flow for manufacturing and delivering the three products to their global customers of Unit 1, are Company 2 outside Location A, a facility at Location F, and Supplier 1.

Product 1, 2 and 3 are based on basic products supplied from Company 1's factories at Location A, modified at Unit 1 to give the finished goods product the performance properties required.

Unit 1 has two categories of customers with differing demands. The two categories are original equipment manufacturers (OEMs) and aftermarket customers (AMCs). OEMs purchase products for their own production and in some cases for their own AMCs, distributors purchasing for their AMCs, and AMCs purchasing for their own needs.

The AMCs, both directly and through distributors, account for more than half of Unit 1's total sales volume for Product 1, 2 and 3. The OEMs consequently account for less than half of Unit 1's total sales volumes for Product 1, 2 and 3.

In order to fulfill the customer demands, Unit 1 has a mixed product delivery strategy of both make-to-order and make-to-stock. For Product 1 and Product 2, both strategies are applied and performed in the same production process flows using the same manufacturing resources. For Product 3 only make-to-order strategy is applied as the product is introduced product to the market newly.

Product 1 and partly Product 3 are based on basic products from almost the entire range of Company 1's thousands of designations. Unit 1 has therefore chosen the basic delivery strategy for these two products to be make-to-order due to the unpredictable customer demand. The order-to-delivery customer lead time is 4-6 weeks for Product 1 and 7-12 weeks for Product 3. For Product 1, the OEMs are the most important customers accounting for more than half of the total sales volume. Since these OEMs can predict their demand and are important as customers, some high runner designations are produced according to the make-to-stock delivery strategy. These designations stand for almost half of the total sales volume of Product 1 and are available from stock for both OEMs and AMCs. Product 3 on the other hand is rather new on the market, with currently low sales volumes. The OEMs account for more than half of the total sales volume of Product 3, but no high runner designations have been identified. Being able to identify high runner designations would enable an additional make-to-stock delivery strategy.

Product 2 has the highest sales volume of the three products. It is based on only 50 basic product designations and has a limited amount of 200 final designations. This makes the customers' demand more predictable than for Product 1 and 3, enabling identification of several high runners. For Product 2, Unit 1 has chosen a make-to-stock delivery strategy for 49 designations, and a make-to-order delivery strategy for the 151 remaining designations with an order-to-delivery customer lead time of 2-3 weeks.

1.2. Problem description

Unit 1 has apprehensions about losing potential sales for the product designations with a make to order delivery strategy. These concerns are particularly directed to Product 3 with the longest order-to-delivery lead times of 7-12 weeks, compared to Product 2 with an order-to delivery lead time of 2-3 weeks.

Product 3 is a new product on the market. Unit 1 expects it to take market shares in similar applications as for the established Product 2, but also to open a large number of new applications areas. Unit 1 has perceived customers to often experience the order-to-delivery lead times for Product 3 too long, compared to both the lead times offered for other products of Unit 1 and to the lead times offered by competitors. The long lead times might inhibit the growth of Product 3, caused by customers rather ordering a proven product with short lead time, than an unproven product with longer lead time.

The apprehensions of losing sales also concern the designations with the delivery strategy make-to-order. As OEMs account for the largest part of the sales volume, Unit 1 wants to increase sales and take market shares to AMCs. The designations with the shortest lead times are the designations made-to-stock, but these are mostly ordered by OEMs and chosen to be stock items due to the predictable demand of the largest OEM customer. The current order-to-delivery lead times of 4-6 weeks for make-to-order designations does not seem to be low enough to attract new AMCs.

These concerns cannot be eliminated by increasing the number of designations having the delivery strategy make-to-stock, due to the increase of tied-up capital required. Currently there is a strong pressure within Company 1 to reduce inventory levels and work in progress, in order to free up tied-up capital in all Company 1’s processes. The options available for Unit 1 are to either change the current strategies in order to make better use of the tied-up capital, or to keep and improve the process flows of the current strategies.

Unit 1 suspects the three product flows to contain non-value adding activities contributing to the long lead times. All current product flows consists of transportations and material handling activities needed when basic products are ordered from Company 1’s warehouses and manufacturing plants, and are sent to Company 2 and to Location F. Especially Product 3 is often shipped by air freight if no basic products are available at Location F. By investigating and analyzing the current product flows, Unit 1 believes that non-value adding activities can be identified and eliminated, leading to reduced lead times.

1.3. Purpose and objectives

The purpose of this master thesis project is to improve the three product flows for Product 1, 2 and 3 in order to reduce their order-to-delivery lead times. These reductions will make the order-to-delivery lead times better conforming to customers’ needs to enable increased sales.

The product flow improvements, which include both the possibilities of modifying the current delivery strategies and eliminating non-value adding activities, have two objectives. The first objective is to achieve direct lead time reductions for the product flows, with lead times exceeding what customers find acceptable, by eliminating waste in both flows and processes.

The second objective is to achieve indirect lead time reductions by increasing the capacity through waste elimination in production processes for all product flows. The capacity is primarily increased in system bottlenecks but also in other processes to prevent internal material queues leading to longer lead times. Since all three flows share the same capacity in Unit 1 Production, waste in one product flow also affects the other product flows.

1.4. Scope

The product flow investigations, mappings and improvements consider four process flows in total: One process flow for Product 1, one process flow for Product 2, and two process flows for Product 3. The first process flow of Product 3 is implemented, and the second process flow is under start up.

Since each product flow consists of mixed delivery strategies where basic products are both kept available in stock and made-to-order, the boundaries of the flow mapping will be adapted to the longest process flow. The boundaries of the flow mappings start at the point in time when Unit 1 receives a customer order or information for refilling a raw material stock, regardless if the customer ordering point is situated further downstream in the same product flow, and ends when the finished goods products is shipped from Location A to the final customer. The flow mappings also include the orderings of shields, seals and graphite for final assembly.

Two process flows for Product 2 contain both the delivery strategies of make-to-stock and make-to-order and both strategies are using the same production resources. Therefore each of the product flows is to be mapped and improved as a total, to develop improvements that are suitable for all product designations, in order to increase the common production capacity and have delivery strategies that fulfill customers' needs. The improvement potentials do not consider how to improve an insufficient production and availability of basic products from the suppliers, but can consider how Unit 1 can handle such problematic situations.

The developed improvements must not increase today's total amount of tied-up capital in processes and flows. If the current delivery strategies are to be modified, only the existing amount of tied-up capital can be used to distribute in a more effective way, due to the current pressure within Company 1 of reducing inventory levels.

All improvements will be summarized in one table for each product where they are structured in four categories; if they are independent or dependent on other improvements, and if they are simple or demanding to implement. The definition of simple is decided as if the proposed improvement easily without any effort can be implemented tomorrow. Due to existing contracts with Company 1's suppliers and business partners, no currently involved external actors can be excluded from the proposed improvements and the future-state product flows.

2. Frame of reference

This chapter aims to describe the theories which are used in the master thesis project. Based on the theories of delivery strategies and the value stream mapping method in combination with complementing interviews the first investigating phase was performed to understand the current state product flows. Based on the theories of lead time reductions and process improvements within Lean production the analysis was performed and improvements for future state product flows were developed.

2.1. Product delivery strategies

There are four major product delivery strategies for a manufacturing company; engineer-to-order, make-to-order, assemble-to-order and make-to-stock. The choice of delivery strategy for a manufacturing company is decided based on a comparison of two factors; the customers' demands, and the ability of the company's own processes to fulfill these demands (Jonsson and Mattsson, 2011).

Among several performance objectives, customers' demand concerns order-to-delivery lead time and flexibility in product type and order volume. The four mentioned product delivery strategies have different performance levels regarding fulfilling these demands and the required amounts of tied-up capital in the processes. The point in time where the customer order is used for customize a product is called *the customer ordering point*. Before this point the material structure; the Bill of material, is generally purchased and refined based on forecast. After the customer ordering point all value adding work is customer driven (Jonsson and Mattsson, 2003).

Engineer-to-order: to develop and manufacture a new customized product generally requires very long lead times for companies. If a customer accepts long order-to-delivery lead times and demands a very specialized product for fulfilling his needs; engineer-to-order is the right delivery strategy. Engineer-to-order has the earliest customer ordering point and requires the least amounts of tied-up capital of the four strategies since no raw material has either been purchased or refined before receiving a customer order.

Make-to-order: if a customer demands a specialized product but doesn't accept the company's lead time needed for product development; the company has to develop several products ready for manufacturing when receiving a customer order. This strategy gives shorter lead times than engineer-to-order due to a later customer ordering point. This provides less product flexibility and requires higher amounts of tied-up capital, since raw material must be available for manufacturing when receiving a customer order.

Assemble-to-order: in order to further decrease order-to-delivery lead times, but still offering nearly as large product flexibility, a modular system can be created. Then basic components, that are same for all product variety, are manufactured in advance based on forecast and can be assembled in different combinations giving product flexibility. The trade-off with this strategy is the amount of tied-up capital that is higher when having manufactured components available in stock for final assembly at the customer ordering point.

Make-to-stock: If the customers' order-to-delivery lead time demand is shorter than the manufacturing company's final assembly and delivery lead times together; make-to-stock is the only effective product delivery strategy. The finished goods products are manufactured based on forecast, which limits the product flexibility, when just having a predetermined types and volumes of products

available in stock for customer orders. The delivery lead time for make-to-stock is the shortest of the four strategies but the amount of tied-up capital is the highest (Jonsson and Mattsson, 2011).
The more value adding work that is put on a product to process it in advance; the shorter lead time to customer, but the higher amounts of tied-up capital and the lower product flexibility is achieved. Based on these four strategies; several combinations of mixed strategies can be created for a product flow. For example when having both high and low runners; make-to-stock is often used for the predictable high runners in order to even out the production workload and thereby save capacity for the unpredictable customer demand for low runners through make-to-order (Olhager, 2000).

2.2. Principles of process improvements in Lean Production

The overall purpose with the business philosophy of Lean Production is to achieve long term success by creating a business culture of continuous improvements. The improvement work aims to satisfy the customer needs through a continuous strive for perfection within all the processes and flows, by reaching highest quality and shortest lead time to lowest cost (Liker, 2004).

The strategy for the improvement work, in order to reach the long term purpose and goals of Lean, is to focus on eliminating three types of problem areas; Muri, Mura and Muda. Muri is about eliminating overburden of man, machine and resources; to strive for sustainability. Mura is about to eliminate unevenness in business processes and outcomes; to strive for stability and reliability. Muda is about eliminating all types of waste by removing all non-value adding time; to strive for as large value adding time percentage of the total lead time as possible (Liker, 2004).

After doing phase 1 in VSM and having mapped the current state flow and its processes, the analysis in phase 2 is based on the strategy of Lean on eliminating the three problem areas. Both the total process flow as a whole and its individual processes is analyzed in order to identify overburden, unevenness and waste that lead to non-value adding lead times, defects and costs. Overburden can be identified as when the production capacity is lower than the average customer demand and pushing operators and machines over their limits. Unevenness can be identified as unstable internal processes regarding quality and lead time, unstable availability and delivery lead time of raw material from suppliers, unstable customer demand of both volume and product mix. In Lean Production there are 8 stated types of waste; overproduction, excess inventories, waiting, over processing, defects, unnecessary transports, unnecessary movements and unused creativity (Rother and Shook, 1999).

When developing improvements for the future state flow the problems need to be tackled in the right order. Before the identified waste can be eliminated, you have to ensure that neither unevenness nor overburden is occurring, because these two problems are often root causes to waste. The right order for performing the improvement work is to start creating sustainability and stability in order to get predictable conditions for the process flow. Principles for achieving this are stabilizing the 4 M:s; man, machine, method and material; leveling out the workload based on the average customer demand; doing right things and things right from the beginning; standardized work methods to ensure right quality. When having achieved sustainable and stable conditions, the improvement work can continue to eliminate all types of waste in the processes flow (Liker, 2004).
In the ideal flow you should strive to achieve a customer demand driven continuous one piece flow with zero defects and minimal lead time. This requires certain improvements that must be implemented in a certain order. To produce according to customer demand with short lead times, smaller batch sizes are necessary. To be able to produce in smaller batch sizes; shorter set up times, a flow layout and smaller buffers are first needed. Then you get the right conditions for leveling your production in both volume and product mix (Liker, 2004).

2.3. Lead time reductions theories

According to Kuhlang, lead time is defined as "that period of time (hours, minutes etc.) required by any process to transform the inputs (materials, customers, money, information) into outputs (goods, services)." The lead times for production are affected by factors like capacity, loading, batching and scheduling. In turn, the lead times affect factors like cost and control. (Karmakar, 1993).

A product flow with shorter lead times has a higher output and increases the value added to the product within a certain time. Alternatively, the same value can be added to the product in shorter time. The aim for the processes is to perform the value added work within the shortest possible time. Sources for reducing the lead times in a product flow are for example process times, transportation time and idle time. (Kuhlang, 2011)

Long lead times entails increasing the costs due to larger buffers, increased uncertainty about requirements, larger safety stocks and broken delivery promises (Karmarkar, 1997), whereas short lead times are beneficial for both the supplier and the customer. In several literature sources on operations management, it is stated that customer demand increases with lower delivery times as well as with lower prices. Consequently, lead times are inversely related to market shares (So, 1998). Reducing the manufacturing lead times allows for the company to react faster to customer demand and by that postpone the production start. A lower share of the products thereby needs to be produced towards forecasts and the risks for stock out or over production are reduced. (Fisher, 1997) The lead times, along with the price, have a large impact on the supplier's possibilities to secure customer orders. The extent to which the supplier is able to deliver the goods within the lead times quoted, may be decisive for where the customers place their orders. Reliable lead times are utterly important for the customers, allowing them to forecast their demand and make plans they can depend upon. These preconditions are difficult to live up to with make to order production. The planning and control of the make to order production are often complicated due to high variations in product range and process times. The complexity is further increased by unforeseen factors affecting the production like breakdowns, employee sick leave and delayed supply of raw material. Additionally, the customers place orders irregularly, causing an uneven demand on the production capacity. The consequence of these factors is that the lead times for make to order production often are long and unreliable (Kingsman, 1989).

3. Method

This chapter describes how the project was conducted, and on what theoretical framework it is based. The research strategy is worked out to provide for a methodical approach to the research and to point out its direction. The different stages for performing the study are described and motivated.

3.1. Preparatory work

The preparatory work was carried out to establish a framework for the study. To create an understanding of the Unit 1 products, an introductory course was given by Development Engineers at Unit 1. To understand the business strategies and help defining the problem, interviews were held with the manager of Business and Design Development at Unit 1. The project framework was established by defining the problem and the expected outcomes.

3.2. Current state study

Within the current state study, there are four stages:
- Collecting data about the customer needs and lead times requirements
- Collecting data about the information flows
- Collecting data about the physical flows
- Mapping the flows

Collecting data about the customer needs and lead times requirements

This stage includes studying the customer needs of having the products delivered within a certain time. The lead times required to fulfill the customer needs were used for comparison when studying the lead times for product flows, and suggesting improvements of the product flows for the future.
To determine the lead times required to fulfill the customer needs, interviews were held with experts in the area. To determine the needs of the OEMs and AMCs; both Company 1 Customer Service representatives and the authorized Company 1 distributors representatives were interviewed.

To determine the overall impression on the customer needs from the supplier's point of view, interviews were held with Unit 1 business representatives, the manager of Business and Design Development at Unit 1, a Business Engineer for the Global Metal Segment and a Business Engineer for the Global Food and Beverage Segment.

As a compliment to the information gathered in interviews, sales statistics were studied to find information about sales volumes and customer ordering habits. The sales statistics were collected from Invoice Line Reports (ILR), retrieved from Unit 1 Business Development.

Collecting data about the information flows

In this stage, the three product flows were studied separately to compare the lead times of the current product flows to the lead times required by the customers. The reason for separating the flows is that they got through completely or partly different production processes. First, the information flows were studied. Data was collected about the product delivery strategies, order handling activities and lead times quoted for the activities required to supply products from customer order to delivery. The data about the product flows was collected in interviews with Unit 1 Supply Chain Manager. Information from actors who were part of the flows and could not be visited, for example international suppliers and carriers, was collected via mail or telephone.

Collecting data about the material flows

In the third stage, the physical material flows were studied. Unit 1 and Company 2 were visited, as well as the warehouses included in the product flows. The study of the material flow started with observations, to give an overview of the processes and order handling procedures in the production.

The study continued with registering the lead times for processes, transports and buffers. The cycle time for each production process were clocked as well as time needed for changeover and order handling procedures. The process times varied widely with the size of the products produced, making it difficult to collect generally applicable data. For a more general picture of the production processes, interviews were held as complements to fill in gaps that the observations could not determine with the manager and operators of Unit 1 Production. For the Product 1 product flow, managers and employees were interviewed at Company 2. Managers and logisticians, at the warehouses included in the flows, were interviewed to determine the lead times for the processes required to handle the incoming and outgoing goods.

Mapping the flows

In the fourth stage, value stream maps were used to summarize the findings of the current state of the product flows. Value stream maps provide a detailed and visual picture of the processes involved. The bottlenecks and sources of waste are clearly highlighted, which is a precondition for identifying and eliminating the non-value adding work (Lee, 2001). When looking for ways to remove the waste, sub optimization of the individual processes is avoided by looking at the entire flow of material and information, i.e. the value stream (Jones, 1996).

The advantage of using value stream maps for presenting the future states is that the value stream map provides a vision of how good the product flow can become, instead of merely a business plan for future development (Brunt, 2010). Further, Value stream mapping is considered the first step when implementing Lean production, with focus on creating value for the customer (Liker, 2004). The approach was found suitable since this study focuses on fulfilling customer needs by reducing lead times. One disadvantage with using value stream maps for the study is that they provide a snapshot of the production processes. The data collected in the interviews held during the earlier stages are assumed to remedy these shortcomings.

3.3. Current state analysis

The lead times for the current state of the production flows were compared to the lead times required by the customers. The comparison showed if the required lead times would be possible to meet with the make to order production of the different products. The future state proposals are not developed to meet the customer needs requiring lead times which not can be met with make to order production.

The information in the value stream maps of the current state were used for identifying bottlenecks and sources of waste in the product flows. Ideas for potential improvements were also collected from the interviews held earlier and from observations made during the study. When analyzing the product flow, it is important to consider the whole flow from the customer order to the supply of the ordered product in order to be able to reduce the waste (Brunt, 2010).

3.4. Future state proposals

When analyzing the current state of the product flows, several improvement proposals where generated. Obvious sources of waste, like transport detours, were removed in the future state proposals. Less obvious improvement proposals were discussed with experts. For improvement proposals concerning the production processes, tests were carried out to verify the results. Before proposing an improvement, information about its feasibility and the preconditions and limitations for implementation was collected in interviews with the managers of the concerned departments. The level of reliability and consistency of information gathered from different sources is evaluated and taken into account when decisions and suggestions are made.

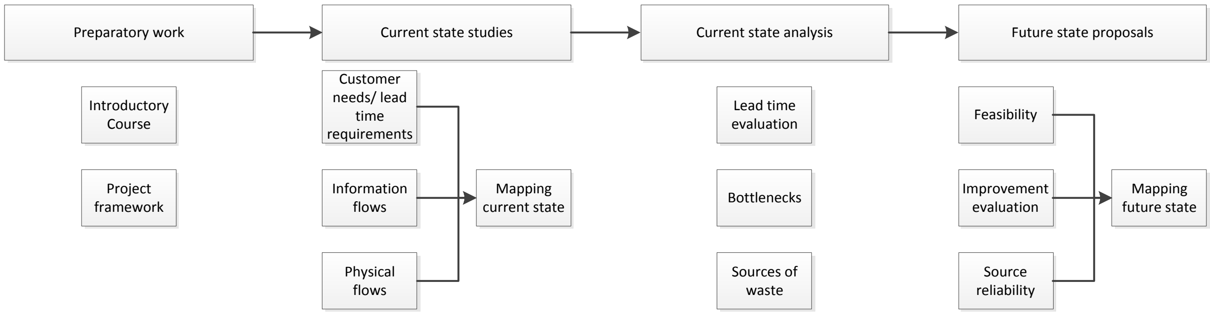

Figure 1. Flowchart of the research strategy

4. Customers’ lead time acceptances

This chapter describes Unit 1’s different customer categories their needs and their lead time acceptances. This information provides for understanding what the purpose and objectives shall be of the thesis, and what they shall achieve in terms of lead times. The information is also used for evaluating if the proposed future state flows are fulfilling their purpose. Unit 1 has three types of customers; OEMs (Original Equipment Manufacturer), AMCs (Aftermarket Customers), and Distributors which serve AMCs. Their needs and lead time acceptances can be divided into three categories depending on how the products are used in their business; non-urgent needs, urgent needs, and new customers or interests.

4.1. Non-urgent needs

Products used as components in production

The first type of non-urgent need is connected to OEMs who purchase products for their own manufacturing business, were products are used as components. Some OEMs also purchase products for supplying their own aftermarket customers. The OEMs have planned production and own stocks of products, which are refilled using a re-order point systems. According to a logistician at Customer Service the OEMs’ most important requirement is to have orders delivered with high dependability. Their re-order point systems for refilling their stocks are based on Unit 1’s order-to-delivery lead times which need to be stable and reliable. The OEMs today accept lead times of about 4 weeks, due to their planned production and own stocks. Since their re-order point systems and stock levels are based on Unit 1’s lead times they encourage Unit 1 to work actively with reducing lead times. That way OEMs would be encouraged to order more frequently in lower volumes, in order to keep lower stock levels.

Products used in production equipment

The second type of non-urgent need is connected to both OEMs and AMCs, who use products in their production equipment and purchase for their own business needs, either directly or indirectly through distributors. Non-urgent needs occur when distributors refill their stocks, when OEMs and AMCs plan to implement new products, or have maintenance periods in their production. In such cases, products are replaced to prevent sudden product break downs which causes stop of production. Customers either order products to be delivered at the date of maintenance, or have products on stock themselves and order products to refill their stock. According to an Account Manager at Company 1 Sales Unit, the lead time acceptance varies between customers and depends on their ability to plan their maintenance periods. Some customers only plan 1 week ahead, but for customers who are good at planning, a lead time of is 4-5 weeks is short enough. According to a Business Engineer at Global Metal Segment, most customers adapt their planning after the led times offered.

4.2. Urgent needs

Products used in production equipment

The second category of customer need is the urgent need. The urgent need is connected to both OEMs and AMCs who use products in their production equipment and purchase products for their own business needs. Urgent needs occur when a customer suffers from sudden breakdowns stopping the production. In this situation time is crucial and the customers need to have a product delivered as soon as possible. To ensure product availability in urgent situations customers either keep products in stock themselves or make agreements with distributors to keep products in stock for their account. According to a District Manager at a Distributor, an Account Manager at Company 1

Sales Unit and a Business Engineer at Global Metal Segment; the customers' lead time acceptance varies depending on the complexity of the product and its process. For small simple products, the customers accept lead times of 12 hours up to 2 days, but for larger complicated products that are highly customized, customers accept lead times of up to 5 days. If lead times are long, customers often order a temporary product with short lead time to use until the right product is delivered.

4.3. New customers and new interests

The third category of customer need is connected to new OEMs/AMCs interested in trying a product, or existing OEMs/AMCs interested in a product which is new to them. Before ordering a product, the customers want to test the product and evaluate its performance before implementation. Not many opportunities are given for testing new products, so the sooner the customer receives the product the more opportunities is available for testing and evaluation. According to the District Manager at a Distributor, the Account Manager at Company 1 Sales Unit and the Business Engineer at Global Metal Segment; if a customer is interested in a new offer, test products must be delivered in about 1 week while the customer is still interested.

Table 1. Unit 1's customers and their lead time acceptances

SUMMARY: Unit 1's customers and their lead time acceptances		
	Customer need category and use of the product:	**Order-to-delivery lead time acceptances and demanded order quantities:**
1.	Non-urgent needs: products ordered for refilling stocks, for maintenance periods and for new product implementations.	< 4 weeks. Large order quantities
2.	Urgent needs: products ordered at sudden product break downs causing stop in production.	12 h - 2 days (simple) < 1 week (complicated). Order quantity: 1-10 products
3.	New customers and new interests: products ordered as problem solvers for testing and evaluation.	1 week Order quantity: 1-10 products

5. The order entry processes

This chapter describes the common processes for all three product flows such as the order entry process and the different Company 1 warehouses used for ordering basic products for final assembly. When customers are interested in ordering an Unit 1's product the order entry process differs with the customer category. OEMs and large AMCs contact a Company 1 Sales Unit's Customer Service, and small AMCs contact a distributor, which are placing orders to different warehouses.

5.1. The IDW and Location B warehouses

Company 1 has several factories and each of them have an Intermediate Distribution Warehouse (IDW). The IDWs are responsible for coordinating the incoming material deliveries and outgoing product shipments of all items produced at the corresponding Company 1 factory. One of these is the IDW for the Location A factory, where all of Unit 1's 3 product designations passes through. All IDWs continuously supply Company 1's Distribution Centre at Location B, OEMs and large AMCs, and Unit 1. The IDWs that supply Unit 1 with basic products, apart from Location A, are located at Location C, D, E F and G.

There are 3 types of orders sent to Location A: stock-order, normal-order or sameday order. Stock-orders are for stock items of which Location A has 3 days to pick and ship from receiving the order, if the products are available in stock. Normal-orders are for non-stock items of which Location A has 2 days to pick and ship, from that the products are registered ready-for-picking (RFP) in the warehouse. Sameday orders must be picked and shipped the same day (within 24 hours) as receiving the order, if the orders are sent before 14:00 and if the products are available in stock. For all order types there is an option to have it transported by air freight instead of truck if it is urgent. According to a logistician at Customer Service, is a sameday order 5 percent more expensive than a normal order. Beside the different picking time for the 3 orders, Location A has 3 days to register a product as ready-for-picking after goods reception. Consequently; a normal order takes 5 days going through Location A; 3 days in and 2 days out to the customer.

Table 2. Company 1 warehouses' order handling lead times

SUMMARY: Company 1 warehouses' order handling lead times		
	Warehouse	**Order categories and picking lead times**
1.	IDW Location A:	3 days for registering as RFP. Stock order (stock items, c-type): 3 days picking time if available as RFP. Normal order (non-stock items, n-type): 2 days picking time if available as RFP. Sameday order: order is picked and shipped the same day if receiving the order before 14:00 and if available as RFP. Is 5 % more expensive than normal orders.
2.	Location B:	Normal order (stock items): order received on day 1 shall be picked and shipped on day 2 if available as RFP. Sameday order: order is picked and shipped the same day if receiving the order before 13:30 and if available as RFP. Is 5 % more expensive than normal orders. Transportation time to Location A: 1 day
3.	Location C:	Picking time: 3 days picking time if available as RFP. Transportation time to Location A: 2 days
4.	IDW Location D:	Picking time: 3 days picking time if available as RFP. Transportation time to Location A: 1 day
5.	IDW Location E:	Picking time: 6 days picking time if available as RFP. Transportation time to Location A: 2 days

Location B is Company 1's regional warehouse that, directly or indirectly via distributors, supplies AMCs on the Location A market and Unit 1. According to a Manager at Company 1 Logistic Services in Belgium, Location B's policy is to maintain availability of products for as many AMCs as possible. Location B does not allow any customer to order such large quantities that would empty the stock, since that may reduce the service to other customers. The customers are instead asked to split large orders so that more customers can fulfill their needs. Unit 1's finished goods products are kept in stock, available for customers' orders, mainly on Location A but also in smaller amounts on Location B. There are mainly 2 types of orders sent to Location B: normal-orders or sameday orders. Normal orders have to be picked and shipped at latest 1 day after receiving the order, if available in stock ready-for-picking. Sameday orders must be picked and shipped the same day (within 24 hours) as receiving the order, if the orders are sent before 13:30 and if the products are available in stock ready-for-picking. For all order types there is an option to have it transported by air freight instead of truck if urgent.

5.2. Customer Service's order entry process

As OEMs and large AMCs order large quantities, they send their orders to a Company 1 Sales Unit's Customer Service. Because Customer Service places their orders to Location A, the OEMs and large AMCs ensure being able to order large quantities, not allowed at Location B, and to avoid the higher price charged by a Distributor. The Sales Unit demands the customers to order large annual order quantities, otherwise the customers are told to place their orders to a distributor.

OEMs and large AMCs base their orders on the delivery lead times of 28 days (4 weeks) quoted by Company 1. Customer Service receive the orders and register its information about product designation, order quantity, delivery date and delivery address in their system. According to a logistician at Customer Service, customers are always offered delivery lead times of at least 4 weeks from receiving the order, even if the ordered designation is a stock item available on Location A. If the ordered product is not available in the system Prod Mast, Customer Service sends the order to the Business team for consultation. If the product is available in Prod Mast, the orders are always placed to Location A. If a customer is having an urgent need, a sameday order is placed to wherever the designation is available, which often is Location B. If the ordered designation is available in stock the order is automatically forwarded to Location A for picking and shipping, according to the registered delivery date. If not available in stock, the order is automatically forwarded to Unit 1 Supply Chain's system to initiate a production order. Then a new delivery date is stated by Supply Chain based on the lead time of the production process. When the order is booked against either the available stock on Location A or a production order, Customer Service receives a confirmation where the delivery date at the customer is stated.

The ordering process of receiving and registering an order in the system has a lead time of about 30 minutes and is always performed during the same day as receiving the order. The production orders are most often created the same day by Supply Chain as order registration. Sometimes they are not, but after sending a reminder the total lead time from order receipt until order booking, is never longer than 24 hours.

5.3. The Distributor's order entry process

Small AMCs who order low volumes send their orders to a Distributor. Distributors sometimes also purchase products for large AMCs if an agreement of keeping stock for urgent needs is made to supply the AMCs instantly from the shelf. The distributors have, through their system, direct contact with Company 1's system and can see product availability on both Location B and the IDWs.

According to the District Manager at the Distributor, all received orders during a day are collected by the Distributor's purchasing system and placed simultaneously to Location B or Location A at 18:00 every evening. The Distributor's system has preregistered warehouses and automatically detects were the requested products are available and place the orders to that warehouse. Primarily the distributors place orders to Location B, whose main role is to supply AMCs, with 2 days shorter picking lead time than Location B. If there is no available stock on Location B, The Distributor's system automatically places orders to an IDW. If products are available on stock on Location B, the order-to-delivery lead time is 3 days until the products reaches The Distributor. If the ordered product is neither available at Location B nor at Location A, the order is automatically forwarded to Unit 1 Supply Chain's system to initiate a production order. 1 day lead time is in this case added to the lead time since Supply Chain only works day time.

If the ordered product is available in ProdMast, the Distributors register the orders in their system and the orders are simultaneously placed to Location B or Location A at 18:00. If the ordered product is not available in ProdMast, the Distributor contacts a Sales Unit's Customer Service, which forwards the order to the Business team for consultation.

5.4. The business team

The Business team is not always consulted if a product is not available in ProdMast. If Supply Chain receives a request of a product that is not complicated to produce it is directly registered in ProdMast. The number of products in ProdMast is limited so sometimes an earlier produced product has been unregistered. Then Supply Chain reregisters the product and initiates a production order. If the ordered product is not available in ProdMast, has never been produced before and is a complicated case the Business team is consulted. This process often starts with an e-mail conversation where the customer sends a request to a Distributor or Company 1 Sales Unit. The Distributor forwards the request to a Company 1 Sales Unit that forwards the request to Supply Chain that forward the case to the Business team. The business team has meetings 3 times a week and investigates the possibilities to assemble, laser mark and pack the product. It consists of 4 people with different expertise where each and every one has 1 day to investigate his area of the problem. According to Unit 1 Business Development, today the case is handled by one person at a time in a certain order: business development → technology → manufacturing → supply chain → offer. The last two steps in handled by the same Supply Chain responsible person. The process lead time for the business team is up to 9 days and if production is approved, Supply Chain initiates a production order.

Table 3. The customer order entry process lead time

SUMMARY: The customer order entry process lead time		
	Customer ordering contact	**Preferred warehouse and ordering lead time**
1.	Customer Service at Company 1 Sales Unit	- Primarily Location A, secondary Location B. - Lead time: < 1 day.
2.	Distributor	- Primarily Location B, secondary Location A. - Lead time: 1 day
3.	Business team	Lead time: < 9 days

6. The Product 1 product flow

This chapter describes the current state of the Product 1 product flow with the delivery strategies and order handling procedures. The problems in the product flow are identified, and improvements are proposed with the intention to meet customer needs.

6.1. Description of the current system

This section describes the delivery strategy and current state process flow of Product 1 from a customer order is received until it is shipped from Company 1's warehouse at Location A to Location B, a Distributor or a final customer.

6.1.1. The delivery strategy for Product 1

Product 1 can be produced from almost the entire assortment of Company 1 basic products. The wide product range makes the customer demand difficult to predict. To provide for maintained high reliability and delivery precision, designations supplied in high volumes are made into stock items. A few of the Product 1 designations are made into stock items, available in stock at Location A for shipping to the final customer within four days. The remaining designations are made to order, with a lead time of 25-37 days from Location B, and 29-44 days from IDWs, according to the lead times summarized in the value stream maps of the total current state. The requirement for keeping the stated lead times is that there are basic products available at the IDWs or Location B for delivery.

6.1.2. The current process flow of Product 1

The information flow for the Product 1 flow includes the information needed to supply the product from customer order to delivery. The information flow includes ordering basic products from Location B or IDWs, booking production of Product 1, and booking packing of the finished Product 1 products, performed by Unit 1 Supply Chain. The filling processes of Product 1 are done at Company 2, and the packing processes are performed at Unit 1.

6.1.2.1. Ordering of basic products and creating an order

Basic products are to a major part supplied from Location B. Occasionally, basic products are supplied from IDWs, located at Location C, D and E. The handling times for picking and shipping is 2 days from Location B and 3-6 days from the IDWs.

The time needed for the shipments from Location B to reach the producing facility outside Location A is 2-3 days and 5-6 days from IDWs. The reason for longer lead times for transports from IDWs, is that they are routed around Unit 1 Production, before being delivered to the producing facility. At Unit 1 Production, the shipments of basic products are redirected to the producing facility and no value adding work is done to the products. These variations in transport routes give a lead time for the basic products from order to delivery to the producing facility between 4-5 days from Location B, and 8-12 days from IDWs.

The time set aside for production in the producing facility is 2-4 weeks depending on the volume produced: Orders below 100 pieces: 2 weeks, more than 100 pieces: 3-4 weeks. When the production of stock items is completed, they are stored in the producing facility until replenishment is needed at Location A. The non-stock items are sent directly to Unit 1 Production for packing and delivery to Location A, via goods reception at D1, for partitioning and shipping to the final customers. The handling time at Location A for non-stock items is 3 days for partitioning and 2 days for picking and shipping to the final customers. The handling time for stock items is 3 days for partitioning and 3 days for picking and shipping. Transports between the producing facility and Unit 1 Production are driven by Company 1 internal transports, called DTS, scheduled three days a week, on Tuesdays, Thursdays and Fridays. This causes extended lead times with up to two days, if the finished Product 1 needs to await the transports to Unit 1 Production. The time set aside for packing at Unit 1 Production is one week. When the packing is finished, Product 1 is sent on a daily basis to Location A for partitioning. The total lead time for the total flow is 4-6 weeks from ordering of basic products until the finished Product 1 is shipped from Location A.

There are also express arrangements available for handling the incoming and outgoing goods at Location A. If labeling the incoming goods "snabbinfackning" (express partitioning) upon delivery to Location A, the goods is partitioned on the same day it is delivered to Location A. The express arrangement used for handling of outgoing goods at Location A is sameday orders.
The ordering activities performed by Unit 1 Supply Chain, when ordering basic products for production and Product 1 for customer delivery, require more manual handling than similar activities for Product 2 and Product 3. The production control system used between the producing facility and Unit 1 Supply Chain does not provide support, which would facilitate the ordering - and replenishment processes. For example, the system does not provide for continuous update on the stock levels of basic products for stock items. As a consequence, there is no automatic information available about when to replenish the stock of basic products. To enable for efficient order handling, excel files with information about stock levels and the production processes, e.g. what orders are under production, are filled out continuously. The manual work required is unnecessary complex and time consuming. The lead time for placing orders is different for orders to Location B and IDWs. The ordering system used between Unit 1 Supply Chain and IDWs offer direct data transfer, unlike the order system used between Unit 1 Supply Chain and Location B which delays the orders until midnight.

Table 4. The lead times of Product 1 product flow

Summary: The lead times of Product 1 product flow	
Process lead time	**Lead time**
Supply of basic products to the producing facility	From Location B: 4-5 days From IDWs: 8-12 days
Production of Product 1 at the producing facility	10-20 days
Awaiting transport to Location A with DTS	1-2 days
Packing at Unit 1 Production	5 days
Partitioning and picking at Location A	5 days
Total process lead time	From Location B: 25- 37 days From IDWs: 29-44 days
Identified problems:	
The minimum order quantity for basic products from Location B/IDWs is sometimes higher than the quantity needed for production.	
No support from the production control system for update and replenishment of stock levels.	
Transport detour for basis products supplied from IDWs.	

The quantities of Product 1 non-stock items ordered by final customers are from time to time low. When Unit 1 Supply Chain places orders for the corresponding basic products to Location B/IDWs, the basic products need to be ordered in larger volumes than requested by the final customer, not to fall below the minimum order quantity allowed by in the system. This leads to that basic products are left over after the production of Product 1. The left over basic products are sent from the producing facility to Unit 1 Production for storage, awaiting new production orders. The storing of basic products both at the producing facility and at Unit 1 Production leads to confusion and adds extra time for handling of orders and material. Provided that Unit 1 Supply is equipped with access to the system, orders can be placed for quantities below the minimum quantity allowed.

6.1.2.2. Product 1 production

The basic products used for Product 1 production are filled with a batter of a polymer. The filling processes are performed either by hand or by a filling machine. The manual filling of Product 1 goes through a sequence of processes, including filling, vacuuming, pressing, baking, cooling and finally dressing. When filling the products by machine, the processes from filling to cooling processes are performed by the machine, allowing for shorter cycle times than for manual filling. For the time being almost all of the stock items are filled by machine.

Production strategy

The stock items are produced in batches, covering ½ - several months of the forecasted demand. With the intention to promote leveling of the production, a production schedule is established, saying that up to three batches of the same stock item can go through the production processes during the same period of time. With this advance planning the stock items can be worked on at more idle times, in order to have capacity when needed for producing non-stock items and urgent orders. Urgent orders are placed to the producing facility, on average a few times a week. The reason for urgent orders is for instance upstream delays or emergent customer needs. The production lead time for urgent orders is 1-2 days. The urgent orders are forced through the production processes, affecting the current production. There are no arrangements established for how to handle the urgent orders to decrease the disturbance of the standard flow

Production preconditions

The wide range of Product 1 leads to many variations in the production flow.
The batch sizes possible to handle simultaneously vary widely with the size of the products. There is only room for a limited number of products in the manual production processes, and products of varying size cannot be baked in the oven simultaneously, since the baking time differs with the product size. Additionally, there are four variants of the Product 1 designations, regular variants and variants specially designed to be approved for the food and beverage industry. The latter is filled with special food grade oil, and must at all times during production be separated from the regular products to avoid contamination. The variations makes it hard to reflect a generally applicable picture of the process times and production lead times.

Production process unpacking:

The basic products delivered to the producing facility are ideally supplied in paper cassettes, containing a large number of products. On occasions, primarily for orders placed to Location B, the basic products are delivered in single piece paper packs. Opening the single piece paper packs when unpacking the basic products adds extra time to the production lead time. If seals are mounted on the basic products, those are removed during the unpacking process. The seals are removed manually, one by one and needs to be handled carefully to be remounted on the products after the filling processes. The process time for unpacking is 1 second for products supplied without seals in cassettes, and 10 seconds for products supplied with seals mounted in single packs.

Production process filling and vacuuming

The manual filling processes starts with placing the basic products in plastic buckets filled with batter. The buckets are placed in a vacuum chamber, with room for three buckets per load. The quantity of products filled per load is restricted by the space available in the vacuum chamber. If the products that are being produced, there is only room for a small number of products in the three buckets. The vacuum removes air to make sure the product cavity is completely filled with batter. After air is let in the chamber, it can be opened and the buckets are removed. The process time for filling is 3 seconds per piece, whereas the time for the vacuuming is 20 minutes per batch.

Production process pressing

During the pressing process, the products are placed on plates, which are stacked on each other in 5 - 6 layers. The plates are held together by a fixture enforcing pressure on the plates to prevent seepage of batter during the baking process. Additional operations are required for those designations of Product 1, which are provided to the final customer with mounted seals. To make room for the seals, which are attached later, shields are mounted on each side of the products before placing the products in the fixture. The process time is 5 seconds without shields, and 15 seconds with shields. Apart from that the mounting process is time- consuming; the shields make the fixtures take up more space in the oven, reducing the oven capacity. The oven capacity is although primarily restricted by the vacuum chamber capacity.

Production process baking and cooling

There are two ovens available, one larger and one smaller. The smaller oven is generally used for baking, and the larger oven is generally used for drying large batches overnight. To increase the number of products baked in the oven each time, the oven could be filled with several batches from the vacuum chamber. Although, the products placed in fixtures cannot wait for baking for more than 20 minutes before the batter starts seeping. Since the cycle time of the vacuum chamber is 20 minutes, only one batch can be awaited before placing the fixtures in the oven. The baking time vary between 1hr 15 min - 3 hrs. When the baking is completed, the products go through two cooling processes. First, the oven is turned off, and the products stay in the oven to cool slowly for 30 minutes. The products are then moved to shelves and the cooling proceeds in room temperature for 20 minutes. When the product temperature has sunk enough, the fixture and shields, if mounted, are disassembled. Because the products stay in the oven to cool after the baking process, the oven needs to be turned on and off several times during the day. Preheating the oven takes 15 minutes, an operation which needs to be attuned to the production flow in order to make the production flow continuously. In the present situation, there are now timekeeping devices available to facilitate efficient use of the oven.

Production process machine filling

The processes from filling to cooling are substituted when filling the products by machine. The process time for filling products is 10 seconds per piece, giving the process time of 6h, 20 min – 8h, and 15 minutes for filling 100 products manually, and 2 h and 11 min for filling 100 products by machine. The factors affecting the decision of machine filling the designations or not are that the tool needed for each designation should be worth investing in. Therefore, a high yearly volume is required. The changeover time is up to 90 minutes for the filling machine. 60 minutes is the actual time for change over. When changing from filling regular batter to batter approved for the food and beverage industry, 30 minutes are added for cleaning the machine. Due to this, restrictions are set to batches only above 150 products are filled in the machine.

Production process dressing

From the dressing process on, all products got through the same manual production flow.

The products are dressed, one by one, to remove excessive batter. The products filled by machine come out clean and only need a quick dress of 10 seconds, whereas the manually filled products have lots of residues, requiring 2 minutes of dressing. Where applicable, seals are now mounted on the products adding 5 seconds per piece.

Production process quality inspection and delivery

While being dressed, the products go through the first of two quality inspection. When being packed in plastic boxes on pallets, the second quality inspection takes place. The non-stock items are prepared for transport to Unit 1 for packing and transport to Location A, via the goods reception at D1, for partitioning and shipping to the final customers. The stock items are placed in storage in the producing facility, waiting to replenish the stock at Location A when the reordering point is reached. The stock items are mostly ordered by OEMs who keep their own storage of components to supply themselves or their customers. When the reordering point of the OEM's stock levels is reached, the stock items are shipped from Location A to the OEMs. This replenishment strategy entails that the stock items are stored in three consecutive storages. One factor affecting the need of stock at the OEMs', is that, according to a Company 1 Customer Service Representative, even though the stock items are ready for delivery from Location A, the quoted lead time for Product 1 to OEM customers is always at least 4 weeks. This approach is used to ensure the delivery precision and reliability demanded by the OEMs.

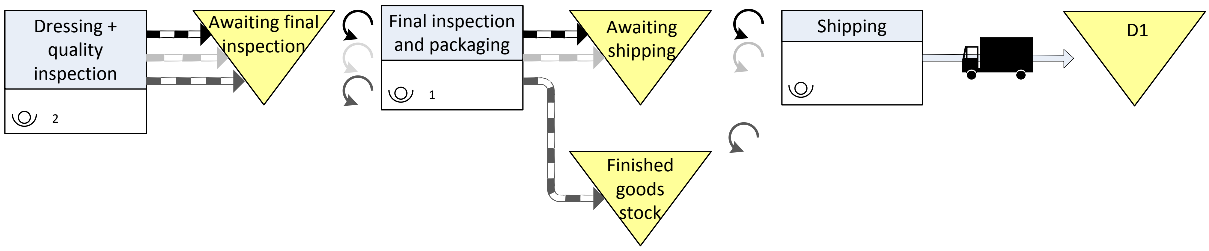

Figure 2. Value stream map of the dressing, inspection and shipping processes

Packing

The time scheduled by Unit 1 Supply Chain for packing and administration of Product 1 at Unit 1 Production, is one week. This time is also used as a safety lead time for catching up on delays caused upstream. The scenario is that actual time available for packing and administration is generally decreased to 1 or 2 days.

The packing of Product 1 is performed manually, or by a pack line. Factors affecting if the products are packed manually or in the pack line is that some product designations cannot be packed in the pack line due to dimension restrictions. There is also a minimum order quantity of 100 products for packing the products in the line, due to the changeover needed between packing of different designations. The pack line consists of 4 machines; plastic machine, packaging machine, labeling machine and bundling machine. The changeover time is 20 minutes for each machine, and if operators organize the changeover process so that one operator changes each machine, the changeover time is minimized. This can be difficult to achieve due to operators being busy performing other tasks, and the changeover time is often extended. When packing Product 1 designations approved for the food and beverage industry, additional 10 minutes are needed for cleaning the conveyor links connecting the machines in the pack line. The cycle times for the packing processes vary widely with the dimensions of the products. In the bundling machine, the paper packs are wrapped in plastic holding the paper packs together in packs of 5 or 10, creating a buffer of paper packs waiting for bundling. The cycle time for each machine is 5-6 seconds and the lead time through the pack line is 5 minutes.

The manual packing processes consists of sticking labels to plastic bags (applicable for some designations), putting products in plastic bags and sealing the bags, putting the plastic bag in single piece paper pack, gluing and labeling the paper packs. The paper packs are placed in pallets with one order per pallet, and are prepared for delivery to Location A for partitioning. The lead time for packing is 15 minutes/10 products. In addition to this, 4-8 minutes per batch are needed for preparations, including printing labels and collecting paper packs.

Table 5. Lead times of Product 1 production

Summary: Lead times Product 1 production	
Process	**Lead time**
Unpacking Filling Vacuuming Pressing Baking Cooling Machine filling Dressing Mounting seals Packing	1-10 sec/ pc 3 sec/ pc 20 min/batch 5-15 sec/pc 1h 50 min-3h 35 min 50 min/batch 10 sec/pc Machine filling: 10 sec/pc Manual filling: 2 min/pc 5 sec/pc 1.5-5min/pc
Process time:	
Production	2h 11 min- 8h 15 min
Packing	32-40 min/100 pcs
Total process time	6h 52 min-8h 55 min + (13-15 h)
Identified problems:	
Basic products supplied in single piece paper packs are time consuming to unpack	
Seals mounted on basic products are time consuming to remove and replace	
Shields mounted during pressing are time consuming to mount, and takes up space in the oven.	
The dressing process for manually filled products takes 2 minutes, compared to 10 seconds for machine filled products	
The changeover time for the pack line is occasionally extended due to low level of organization	
No production establishments for urgent orders	

6.1.4. Are customers' needs fulfilled?

When comparing these lead times to the lead times required to meet customer needs, it is shown that no customer needs are fulfilled with the make to order production. With the make to stock production, the non-urgent and urgent needs are fulfilled.

Table 6. Lead times of Product 1 product flow

Summary: Lead times Product 1 product flow	
Process	**Lead time**
Picking and shipping of basic products to the producing facility	From Location B: 5 days From IDWs: 8-12 days From Japan: < 3 months
Production	10-20 days
Packing Unit 1 Production	5 days
Partitioning and picking at Location A	5 days
Picking stock items at Location A	3 days
Total order to delivery lead times	
Stock items:	4 days + transport time
Non- stock items:	From Location B: 25-35 days + transport From IDWs 32-42 days + transport
Lead times required to fulfill customer needs	
Non-urgent needs	< 20 days
Urgent needs	< 2 days
New interests	< 5 days

6.2. Analysis

This section describes the analysis of the current system, what customer needs Unit 1 should focus on based on the conditions for their processes and what problems that are identified that stops Unit 1 from fulfilling the focus needs in the current process flows.

6.2.1. Focus needs

The process times calculated in the current state leads to the conclusion that the make-to-order production cannot meet the urgent needs. On the basis of these conclusions, the improvement proposals for the future state are developed to meet the non-urgent needs and the new interests.

Table 7. The potential to meet customer needs with Product 1 make to order production

Summary: Potential to meet customer needs with make-to-order production		
Total process time		6h 52 min-8h 55 min + (13-15 h)
Customer needs	**Required lead times**	**Can needs be met with MTO**
Non-urgent needs	< 20 days	Yes
Urgent needs	< 2 days	No
New interests	< 5 days	Yes

6.2.2. Problems of fulfilling the focus needs in the current system

Summarizing the problems described earlier, the following problems have been identified to extend the lead times for the Product 1 product flow.

Table 8. Problems increasing the lead times in the Product 1 product flow

Problems increasing the lead time for the Product 1 product flow	
Problem	**Lead time increase**
Transports from IDW routed around Unit 1	1 day
Awaiting DTS transports to and from the producing facility	1-2 days
Basic products supplied with grease	13-15 h/batch
Basic products supplied with seals mounted, in single pack	10 sec/ pc
Partitioning picking and shipping of non-stock items at Location A	5 days

6.3. Proposals for an improved future system

This section describes the objectives for the future state flows and the improvements needed to achieve the objectives and to fulfill the customer needs.

6.3.1. Objectives for the future state flows

To meet the two categories of needs, it is proposed that one standard and one fast flow are implemented. The standard flow is proposed in order to enable for meeting the non-urgent needs with lead times from customer order to delivery of up to 4 weeks for production. The lead times for production and packing in the standard flow are set to allow for large order volumes to go through the production flow. The fast flow is proposed to meet the new interests, with lead times from customer order to delivery of up to one week. The lead times for production and packing are set to allow for small volumes, up to 10 pieces, to go through the production flow.

6.3.2. Improvement proposals for the future state standard flow

The standard flow includes improvements of the current state of the product flow, leading to lead time reductions of transportation, material handling at warehouses and production processes. Some of the improvements need to be implemented in a certain sequence to make sure all required preconditions are available. Other improvements can be implemented regardless of other actions taken.

6.3.2.1 Improvement proposals to be implemented by Unit 1

Basic product supply

The future transports of basic products are suggested to go straight from the hub at Location A to the partner in the producing facility, as opposed to today when transports from IDWs are directed via Unit 1. Rerouting of the transports for basic products supplied from IDWs will decrease the lead time by 1 day. In addition to the time savings, the handling activities will be decreased since three warehouses are removed from the flow. In the case that basic products are supplied from the storage at Unit 1, these will be sent with the internal Company 1 transports operating 3 days a week. However, future unused basic products will be stored at the partner in the producing facility, leading to that the storage of basic products at Unit 1 eventually is consumed.

Order handling

The communication between Unit 1 Supply Chain and the producing facility would further be facilitated by using an electronic ordering system called Supply Integration Manager. Using SIM would allow for automatic updates on stock levels, and provides for a decreased amount of manual work. To facilitate the ordering handling activities between Unit 1 Supply Chain and the producing facility, Unit 1 Supply Chain should be equipped with access to ordering the quantity needed for orders falling below the minimum quantity stated in the system. That would eliminate that excess basic products are left over after production. The storage of basic products would be concentrated to one location and the order- and material handling activities would be decreased.

To establish direct contact between Unit 1 Supply Chain and Location B would eliminate the order delay, saving the lead time of one day for order placements. It would also provide for Unit 1 Supply Chain to place same day orders to Location B when basic products are needed urgently. The flexibility for urgent orders would be higher if they could be placed by Unit 1, and not only by Company 1 Customer Service, which is the case today.

It suggested that all basic product designations are ordered and supplied to the producing facility in cassettes and without grease and seals, to the largest extent possible. The time saved for eliminating the process for seal removal is 9 seconds per piece

Packing and marking

It is suggested that the packing and laser marking of Product 1 products is moved to the producing facility. The benefit of this change is that the production of the Product 1 product would be performed by the Partner in the producing facility exclusively. The capacity freed at Unit 1 and the warehouses excluded from the future flow, can be used for value adding work for the Product 2 and Product 3 product flows. The preconditions for moving the packing and marking operations of Product 1 to the producing facility are that a laser marking machine is installed at the partner's plant. Further, supply and storage of paper boxes need to be arranged. Assuming that the laser machines, that will be installed in the producing facility, has the same cycle time as the one available at Unit 1 Production, the marking process will take 5 seconds per product. It is suggested that Product 1 initially is packed manually, although choosing either way of packing does not make a major difference in terms of lead time. The studies conducted show that the cycle time for packing 100 products by hand is 45 minutes, and by machine 48 minutes. The process time for marking and packing 100 products at the partner in the producing facility is 53 minutes. The capacity needed for packing the products and operating the marking machine should not be provided from the dressing process which is the bottleneck of the flow.

In the time of the study, 5 workdays are set aside at Unit 1 production for administration and packing of Product 1. On the basis of the mapped process times, one day seems reasonable to add to the lead time when moving the packing and marking processes to the producing facility. Moving the packing and laser marking of Product 1 to the producing facility would reduce the lead time for the packing process from 5 days to 1 day. The concentration of production to the producing facility improves the material handling efficiency. Reducing the handling of materials is one way to reduce waste for lean production (J. Liker, 2001).

Express partitioning

Given that the packing and laser marking processes are moved from Unit 1 to the producing facility, the lead time for transports can be reduced by rerouting the shipments of Product 1 from the producing facility to Location A. In the current state, Product 1 is sent to Location A via a goods-reception terminal D1 for transport to Unit 1 Production. Rerouting the transports directly to terminal 9 floor 100, eliminates the material handling activities at D1 and Unit 1 Production, saving lead time and capacity. By establishing express partitioning as a standard procedure for partitioning incoming goods at Location A, the lead time for partitioning, picking and shipping at Location A is reduced from 5 to 2 days for make to order products.

Stock concentration

To fully take advantage of moving the packing and marking from Unit 1 Production to the producing facility, it is suggested that the stock of Product 1 is phased out from Location A, and concentrated to the producing facility. The improvement would free tied-up capital which could be used to make more designations into stock items. The benefit of more stock items is that the supply of basic products becomes more stable. The drawback of this suggestion is the extension of the time needed for supplying the final customers with stock items from 3 days to 6-7 days.

Table 9. Preconditions and savings accomplished for the Product 1 standard flows

Summary: Improvement proposals to be implemented by Unit 1 – standard flow	
Preconditions to fulfill by Unit 1	**Savings accomplished**
Use the electronic ordering system for information between Unit 1 Supply Chain and the producing facility	Enables for improved communication and decreased amount of manual work
Establish access to order volumes falling below minimum volumes stated in the system	Eliminates ordering exceeding the needed quantity. Basic products will be stored at only one location
Establish arrangements for Unit 1 Supply Chain to place orders to Location B without delay	1 day lead time reduction when placing orders to Location B for basic products
Order basic products without seals, packed in cassettes	9 sec lead time reduction/piece
Transport basic products ordered from IDWs directly from the hub to the producing facility	1 day lead time reduction
Move packing and marking from Unit 1 Production to the producing facility	4 days lead time reduction for packing
Transport the Solid products from the producing facility to IDW terminal 9, floor 100. Use express partitioning of Product 1 at Location A as standard procedure	3 days lead time reduction
Phase out the stock of Product 1 at Location A. Keep stock of Product 1 in the producing facility exclusively	Frees tied up capital which can be used to increase stock of basic products in the producing facility
Increase number of stock item designations	Provides for securing the supply of basic products and filling more designations by machine. Preferably used for basic product designations with long delivery lead times

Upon shipping to the customer, Product 1 will be transported to IDW for partitioning and transshipment with other Company 1 products. The time from when the production is completed until the finished goods reaches Location A is 1-2 days. The handling times at Location A, for non-stock items, are 3 days for partitioning and 2 days for picking and shipping to the final customers. For stock items, the handling time is 3 days for partitioning and 3 days for picking and shipping. The suggested improvement would decrease the lead time for picking and shipping by 1 day since the Product 1 designations would not be considered stock items at Location A. The extended lead time in the future state flow would probably not decrease the customer service.

Remarks

At Unit 1 Production, Product 1 is supposed to go through a laser marking process where the designation code gets engraved, identifying the product type and its dimensions. At the time of the study, the laser marking is not yet included in the process flow due to unsatisfactory quality of the marking. Therefore, the products are delivered to the final customers with the designation code of the basic product engraved, and the designation code of Product 1 only marked on the paper box they are delivered in. The attempt is to set the process in order shortly, since correct marking is of outmost importance for the final customers and their chance to order the right replacements. By suggesting that the marking is moved to the partner in the producing facility, it is assumed that the initiation of marking Product 1 will not be delayed.

6.3.2.2. Improvement proposals for Product 1 production – machine filling

The proposals for reducing the lead time for the Product 1 production consist of two proposals: One for the manual filling processes, and one for the machine filling processes. Since the machine filling has significantly lower lead time, it is suggested that the number of designations filled by machine is increased. Allowing for larger batch sizes, and by that establishing the preconditions for filling by machine, is made possible by concentrating the stock of Product 1 to the producing facility. The capital freed when phasing out the stock at Location A can be used for increasing the stock of basic product at the producing facility. This proposal is particularly beneficial for basic products with long delivery lead times, for example the stainless steel designations supplied from external suppliers. Keeping basic products in stock at the producing facility allows for production of designations with high yearly demand in large batch sizes, which are the prerequisites for filling by machine.

To be able to reduce the batch size required for machine filling, which is approximately 150 pieces, it is suggested that the change-over process for the filling machine is systematically gone through. If the change over time can be reduced, the batch size required for filling can be reduced, allowing for designations with high yearly demand to be filled by machine even in lower batch sizes.

6.3.2.3. Improvement proposals for Product 1 production – manual filling

Vacuum chamber capacity

It is suggested that the capacity of the vacuum chamber is increased, in order to optimize the efficiency utilization of the dressing process, the constraining process of the production flow. In the present situation, the vacuum chamber has lower capacity than the following processes. By providing for larger batches in the vacuum chamber, the number of products going through the processes can be better adapted to the dressing process. Higher capacity in the vacuum chamber can be achieved by optimizing the space taken up in the chamber. This can be done by placing more of the existing buckets with batter in the chamber. Containers with a size and shape more suitable to efficiently use the size of the chamber could also be developed.

Standardized working schedule for manual filling processes

To reduce the production lead time for products filled manually, it is proposed that the work performed during the manual filling processes is standardized. The purpose with standardizing the work is to perform process in parallel, when applicable, in order to produce five batches per day as can be seen in figure 4. The X-axis represents time from 08:00 to 18:00 and the Y-axis represents the five batches. According to this schedule, cooling in the oven is performed in parallel with filling and vacuum. Pressing is also performed in parallel with preheating the oven.

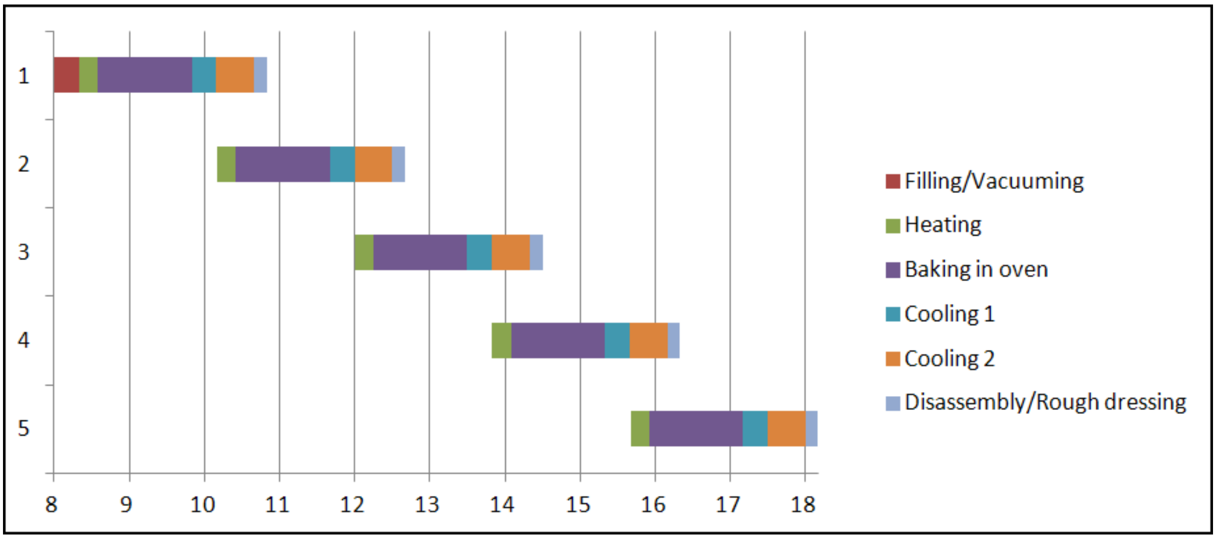

Figure 3. Standardized manual filling process of Product 1 production

To fully use the capacity available, it is suggested that the manual work is standardized and performed according to working schedule. It is also suggested that batch sizes are adapted to the process time of the oven, which is the process preceding the dressing. Proposed batch sizes are calculated with the premises to eliminate the idle times for the dressing process. To reduce the negative effects of the constraint, the capacity and utilization of the other processes are adapted to the dressing process.

The lead times for the processes derive from the mappings of the current state of the product flows. The setup of the production manning is based on the capacity available in the producing facility at the time of the study, with two operators working at the manual filling processes. Operator one continuously dresses the products without interruptions for handling other tasks. Operator two is responsible for the filling processes: filling, vacuum suction, pressing, baking, cooling and disassembly. While the oven is preheated the products that will go in the oven are pressed. While the products are cooling in the oven, operator two can fill the following batch. No efficiency losses are included in the calculations. The lead time used for the dressing process is 10 seconds for machine filled products, and 120 seconds for manually filled products. These process times were derived during observations and discussions with the operators at the producing facility. However, the process times vary widely with the size of the products. Therefore, the calculations made for finding an appropriate batch size for increasing the capacity utilization of the dressing should be seen as an example for how the lead times can be reduced.

Table 10. Standardized working schedule for operator 2 in Product 1 production: 1 production run

Working schedule for operator 2, manual filling, 1 batch	
Processes performed by operator 2, with the batch size of 83 products:	
1.	Place basic products in buckets for filling. Place buckets in vacuum chamber. 4 minutes.
2.	Turn on vacuum chamber. **Dressing for 15 minutes**
3.	Vacuum suction completed, air let in. In parallel, the products cooled slowly in the oven are removed for cooling in room temperature. Turn on oven.
4a	<u>Without shields:</u> Pressing products. Excessive batter returned to buckets, buckets returned to vacuum chamber**.** Place products in oven. 7 minutes, + 2 minutes for preparations. **Dressing for 15 minutes**
4b	<u>With shields:</u> Pressing products. Place products in oven. Excessive batter is returned to buckets, buckets returned to vacuum chamber. 20 minutes, + 2 minutes for preparations. **Dressing for 2 minutes**
5.	Disassemble product fixture, dress roughly and place in boxes awaiting dressing. 5 minutes. **Dressing for 40 minutes**
6.	Go back to step 1

Table 11. Standardized working schedule for operator 2 in Product 1 production: 2 production runs

Working schedule for operator 2, manual filling, 2 production runs	
Processes performed by operator 2, with the batch size of 75 products:	
1.	Place basic products of batch 1 in buckets for filling. Place buckets in vacuum chamber. **2 minutes/ 35 products.**
2.	Turn on vacuum chamber. **Dressing for 15 minutes**
3.	Let air in in vacuum chamber. **Dressing for 5 minutes**
4	Press batch 1. 4 minutes (+2 minutes for products with shields). 10 minutes (+2 minutes for products without shields)
5	Turn off oven, let products cool.
6.	Return excessive batter to the buckets. Place products of batch 2 in bucket for filling, place bucket in the vacuum chamber. 2 min/35 products.
7..	Turn on vacuum chamber **Dressing for 15 minutes**
8.	Vacuum suction completed and air is let in. In parallel, batch 2 have been cooling in the oven are removed and put on shelves for cooling in room temperature. Turn on oven.
9a.	<u>Without shields:</u> Press products of batch 2. Excessive batter returned to buckets. Buckets returned to vacuum chamber. Place both batches in oven. 4 minutes + 2 minutes for preparations. **Dressing for 20 minutes**
9b.	<u>With shields:</u> Press products of batch 2. Excessive batter is returned to buckets. Buckets returned to the vacuum chamber. Place both batches in oven. 10 minutes + 2 minutes preparations. **Dressing for 15 minutes**
10.	Disassemble product fixture, dress roughly and place in boxes awaiting dressing. 10 minutes **Dressing for 10 minutes**
11.	Go back to step 1

Two scenarios are presented in table 10 and 11. The premises for the two scenarios are that the calculated ideal batch size can go through the processes without being split. Calculations are made for the whole batched produced at the same time for smaller products, and the batch being divided in two production runs for larger products.

The calculations are based on the number of non-stock items possible to dress during the process time for baking and cooling in the oven, which is 110 minutes. According to calculations done, using sales statistics, the share of sales volumes accounting for stock items filled by machine, a suitable batch size for producing the whole batch size in one run is 83 products. 50 products would be dressed by operator one, and 33 products would be dressed by operator two. If divided into two production runs, a suitable batch size is 75 products. 49 Products would be dressed by operator one, and 26 products by operator two.

Table 12. Summary of improvements for Product 1 production

<table>
<tr><th colspan="2">SUMMARY: Standard Flow, Product 1 production lead time of 8 days</th></tr>
<tr><th>Preconditions</th><th>How to meet the preconditions</th></tr>
<tr><td colspan="2">Proposal 1: Machine filling</td></tr>
<tr><td>Machine filling of designations in large batches with high yearly customer demand</td><td>Increased volumes of stock item designations provides for production in large batch sizes</td></tr>
<tr><td>Machine filling of designations in small batch sizes with high yearly customer demand</td><td>Systematically go over the changeover process for the filling machine to reduce change over time to reduce the batch size limit for machine filling.</td></tr>
<tr><td colspan="2">Proposal 2: Manual filling</td></tr>
<tr><td>Increase the utilization of the constraining dressing process</td><td>Standardize the manual filling processes</td></tr>
<tr><td>Adapt the batch sizes to the process time for dressing</td><td>Ensure that the processes before the dressing have room for the determined batch sizes. Follow a working schedule where processes are performed in parallel when possible. Use time keeping devices to follow the scheduled times</td></tr>
<tr><th colspan="2">SUMMARY: Improvement proposals for Product 1 production – standard flow</th></tr>
<tr><td colspan="2">Increase the capacity in the vacuum chamber. Larger batch size provides for higher efficiency in the constraining dressing process</td></tr>
<tr><td colspan="2">Standardize the manual filling processes and establishing a working schedule based on ideal batch sizes. Optimizes the dressing capacity and reduces the lead time for non-stock items</td></tr>
<tr><td colspan="2">Phase out the stock of Product 1 designations at Location A. Frees tied up capital which can be used to increase the number of Product 1 stock item designation.</td></tr>
<tr><td colspan="2">Increase the number of stock item designations in the producing facility. Decreases the lead times for basic product supply and provides for filling more designations by machine.</td></tr>
<tr><td colspan="2">Systematically go over the changeover process for the filling machine. Reduced changeover time provides for filling non-stock items with high yearly demand by machine.</td></tr>
<tr><td colspan="2">Increase the number of designations filled by machine. Frees capacity in the dressing process</td></tr>
</table>

6.3.3. Improvement proposals for the future state fast flow

The fast flow is proposed to meet the needs of the new interests with a lead time from customer order to delivery of up to five days. The fast flow improvement proposals are partly based on proposals made for the standard flow. Preconditions for making the fast flow a sustainable solution is that there are routines and standards are established, making the fast flow a part of the standard production routines. By phasing out the stock at Location A and keeping the stock of Product 1 designations at the producing facility exclusively, prerequisites are established for being able to send Product 1 shipments directly from the partner to the final customer.

The basic product will be supplied to the producing facility by placing same day orders to Location B/IDW. The same day orders are placed in the order handling system used by Company 1 Customer Service. To allow for Unit 1 Supply Chain to place same day orders, they need to use the order handling system used by Customer Service. Alternatively, the orders can be arranged to be placed by Company 1 Customer Service.

The lead times when placing same day orders are cut with 1-2 days when ordering basic products from Location B, and cut with 3-4 days when ordering from IDWs. To reduce the transport times in the fast flow, the Company 1 internal transports operating three days a week will not be used. The transports that used in the fast flow are called FTC (Final Transport to Customer) and are booked, as the same day orders, in the order handling system used by Company 1 Customer Service. The FTC are arranged to pick up goods at the hub, the day after the goods is delivered to the hub, for transport to the producing facility**.** Similarly, the finished Product 1 will be transported by FTC from the producing facility to the final customer. This improvement eliminates the delay caused by awaiting the transports to Location A and the partitioning and picking procedures at IDW is avoided. For time critical emergency orders there are several possibilities of using air freight. The orders can be sent with the next flight available and delivered within the shortest possible time. However, these delivery options require extra work and are not considered to be a suitable part of a standardized fast flow. The products will be forced through the production, allowing one day for completion. The lead time for the fast flow will be 1 week from customer order to delivery. The time is according to the research done, short enough to maintain the customers' interest in the product.

Table 13. Summary of Product 1 fast flow preconditions

Summary: Improvement proposals for the future state fast flow	
Preconditions	**Savings accomplished**
Establish arrangements for Unit 1 Supply to use ordering system allowing for placing same day orders to Location B and booking FTC orders. Alternatively, Company 1 Customer Service place orders transport	From Location B: 1-2 days lead time reduction From IDW: 3-4 days lead time reduction
Products are forced through the production	Production can be completed in one day
Move packing and marking from Unit 1 Production to the producing facility	Product 1 can be shipped directly from the producing facility to the final customer

6.3.4. Expected results

The improvements suggested for the standard flow reduce the lead times from customer order to delivery from 25-44 days for the current state to 15-20 days for the future state, fulfilling non-urgent needs. The improvements suggested for the fast flow reduce the lead times to 4-6 days, fulfilling the needs of new interests and customers.

In the future state proposals, the producing facility is given eight days for production and packing of Product 1. This together with the lead times for the other processes gives a total lead time of 15-17 days from Location B and 18-20 days from the IDWs. The lead times with basic products supplied from Location B meet the non-urgent needs well, whereas the lead times with basic products supplied from IDWs just meet the non-urgent needs. As the basic products to a large extent are ordered from Location B, the lead time from customer order to delivery will primarily be 15-17 days. This gives 3-5 "unused" days to distribute between the processes, if needed, before the limit of 20 days of required lead time for non-urgent needs are reached. This arise the question of allowing 10 days for completing the production and packing at the producing facility, instead of 8 days. Allowing 10 days for production is the same lead time used today for production of volumes below 100 products.

Table 14. Summary of Product 1 standard flow processes

Summary: Standard Flow processes and lead times		
	Processes	**Lead time**
1.	Unit 1 Supply Chain receives customer order and places order for basic products to Location B/IDWs. DTS transport	From Location B: 4-5 days From IDWs: 7-8 days
2.	The producing facility receives basic roducts. FIFO flow through production, marking and packing	8 days
3.	Product 1 transported from the producing facility to Location A	1-2 days delay for awaiting transport
4.	Delivery to Location A terminal 9 floor 100, for "express partitioning", picking and shipping.	2 days
5.	Transport and delivery from Location A to final customer	2 days
	All processes	**From Location B: 15-17 days + transport time** **From IDWs: 18-20 days + transport time**

Table 15. Summary of Product 1 fast flow processes

Summary: Fast flow processes and lead times		
	Processes	**Lead time**
1.	Unit 1 Supply Chain receives customer orders and on the same day places FTC orders for transport of basic products from Location B/IDWs.	From Location B: 2-3 days From IDWs: 3-4 days
2.	The producing facility receives basic products. Prioritized flow through production, marking and packing	1 day
3.	Product 1 transported from the producing facility to the hub in Arendal.	1 day
4.	Delivery to final customer	2 days
		From Location B: 4-5 days + transport time **From IDWs: 5-6 days + transport time**

7. The Product 2 product flow

This chapter describes the current state of the Product 2 product flow with the delivery strategies and order handling procedures. The problems in the product flow are identified, and improvements are proposed with the intention to meet customer needs.

7.1. Description of the current system

This section describes the delivery strategy and current state process flow of Product 2, from a customer order is received until it is shipped from Location A to Location B, a distributor or a final customer.

7.1.1. Delivery strategy for Product 2

Product 2 is a special product developed for highly demanding applications, such as contaminated or extreme temperature environments. It has the highest sales volume of the 3 products, with a share of well over half the total sales volume according to sales statistics from 2011.

Product 2 is based on 50 designations of basic products with 4*3 special clearance, made-to-order for factories at Location C, E and G. The basic products are either mounted with dry lubricant graphite components, working as a cage, or filled with graphite grease. Both variants are produced at Unit 1 Production at Location A. Each of the 50 basic designations can be modified into 4 final variants giving a limited amount of totally 200 final designations:

item1: products with cage and without shields, filled with graphite grease.
item2: products with cage and 2 shields, filled with graphite grease.
item3: products with 2 shields and without cage, mounted with small graphite segments.
item4: products with 2 shields and without cage, mounted with a graphite crown.

The limited amount of totally 200 final designations makes the customer demand more predictable than for Product 1 and Product 3, enabling identification of several high runners. This has made Unit 1 choose a make-to-stock delivery strategy for 49 final designations and a make-to-order delivery strategy for the 151 remaining final designations with an order-to-delivery lead time of 2-3 weeks. About 25 of the 151 final make-to-order designations are having an additional make-to-stock strategy, without being official stock items, where a half month's demand is produced and kept in stock at Location A. The two delivery strategies use the same production process flow and the same manufacturing resources. The 50 basic product designations are ordered from Company 1's factories and kept available in Unit 1's warehouse at Location A awaiting final assembly. The graphite separators are kept available in stock at a supplier but the graphite grease is kept in stock at Location A. When receiving a customer order or getting a signal from the system to refill the finished goods stock; graphite components are ordered from the supplier, graphite grease is ordered from D3 Basement, and basic products and shields are ordered from Terminal A to be assembled in Unit 1 Production.

7.1.2. Current state process flow of Product 2

The product flow of Product 2 is divided into 3 parts. The first part contains the ordering of basic products and shields to be kept on stock at Location A. The second part contains the process of phosphating the basic product designations and shields to be kept phosphated at Terminal A awaiting final assembly. The third and final part contains the processes of ordering phosphated products and shields from Terminal A, graphite components from the supplier, and graphite grease from D3 Basement, to be assembled at Unit 1 Production and sent to final customer or the finished goods stock at Location A. There are 2 customer ordering points in the product flow of Product 2. The first customer ordering point situated at Terminal A, when ordering phosphated products, shields and graphite for final assembly in the MTO-product flow. The second customer ordering point is situated at the stock at Location A when ordering finished goods designations from the stock in the make to stock product flow.

7.1.2.1. Part one: ordering of basic products and shields

Ordering limitations from the factories

Once every month the Manager of Unit 1 Business and Design Development create a forecast for Supply Chain to register in their system. Based on this forecast and historical sales statistics an optimal batch size is calculated by the system for each of the 50 basic product designations that can be modified into 200 final designations. According to two Supply Chain Managers at Unit 1, the ambition is to have phosphated products equivalent to 1 batch size for each of the 50 basic product designations available in stock at Terminal A for final assembly. Company 1 factories where the basic products are ordered from demand a minimum order quantity that is 1-13,5 times larger than the system's recommended batch sizes. The data showing the optimal batch sizes from the system and the minimum order quantities from the factories is given in a document called "Crosscheck partistorlek vs. rålager Product 2" provided by one of the Supply Chain Managers. When comparing the total volume of all designations' batch sizes with the total volume of all designations' minimum order quantities the data in this document show that the total order quantity ordered from the factories is 4,4 times larger than the total volume needed. This means that there is 4,4 times more basic products ordered to refill the stock at Terminal A than Unit 1 needs for the production of Product 2. This is mainly due to that the basic products are only manufactured make-to-stock in the factories and the special clearance designations require long set-up times in the production lines.

Basic products ordered both with and without cage

Most of the basic products are ordered and manufactured with cage and balls at the factories. Since 2 of the 4 final variants (item3 and item4) have graphite separators instead of a cage, 10 basic product designations are ordered and manufactured with balls only at the factories. When manufacturing products without cage and with large clearance, there is a high risk for the product to fall apart. 7 of the 10 basic product designations that are ordered today without cage are falling apart and have to undergo a bundling process at Unit 1 Production before phosphating at Company 3.

Table 16 shows a comparison between the 10 designations that are ordered without cage today and designations with as high sales volumes that are only ordered with cage. The reasons for choosing these 10 designations are according to a Supply Chain Manager at Unit 1, that these designations have a low risk of falling apart in combination with quite high sales volumes. As can be seen in the table below; 7 of the designations ordered without cage fall apart. The designations exclusively ordered with cage have almost the same risk of falling apart and same sales volumes. These designations are not ordered without cage today however. The data about the sales statistics are taken from statistics for 2011.

Table 16. Comparison between Product 2 basic products ordered with cage and without cage

Basic product designations ordered without cage vs. examples of basic product designations only ordered with cage:	
Basic product designation	**Number falling apart as 4*3**
10 basic products ordered both with and without cage.	70 %
Basic products ordered only with cage.	90 %

The remaining basic product designations that will be modified into an item3 or item4 final variant, and not have been ordered without cage from the factories, have to undergo a cage removing process before final assembly at Unit 1 Production.

The order-to-delivery processes and their lead time

Supply Chain's system gives continuously proposals for refilling the stock of basic products based on forecasts, customer orders and the known lead time from the factories. When the system gives a signal to refill the stock, Supply Chain orders basic products from the factories with order-to-delivery lead times of 40-80 days. Shields are ordered from suppliers to Terminal A with order-to-delivery lead times of 25-80 days. The products and shields are registered at Terminal A after 1 days lead time and kept in stock awaiting phosphating orders. Due to the large minimum ordering quantities from the factories, the space available for Unit 1 at Terminal A is currently full. From the beginning Terminal A offered Unit 1 172 pallet places in their racking but now they have expanded it to over 200 for handling all the goods.

Table 17. First part in Product 2 product flow: ordering basic products and shields

SUMMARY: Ordering basic products and shields	
	Total order-to-delivery lead times:
	- Products from Location C, E and G: 40-80 days - Shields from suppliers: 25-80 days
	Identified problems:
1.	The minimum order quantities from the IDWs is 1-13,5 times larger than the optimal batch sizes recommended by Supply Chain's system.
2.	The available storage space at Terminal A for Unit 1's products is full.
3.	Several designations are not ordered without cage although they have both higher sales volumes and the same risk of falling apart as the ones ordered without cage.
4.	Most basic products without cage falls apart which demands a bundling process.
5.	Basic products not ordered without cage has to undergo a cage removing process.
6.	Long order-to-delivery lead times of 40-80 days for products and 25-80 days for shields.

7.1.2.2. The second part: phosphating of basic products and shields

Initiating phosphating of products and shields

Supply Chain's ambition is to have 1 batch of phosphated products and shields for each basic product designation available in stock at Terminal A. Terminal A only handle material in full pallet quantities, due to the lack of repacking equipment and space for installing it. Since the minimum order quantities from the IDWs are 1-13,5 times larger than the batch sizes and full pallets, only, are sent by Terminal A to Company 3 for phosphating, the available stock of phosphated products is up to 4,4 times larger than needed.

The phosphating process starts with Supply Chain sending an e-mail order to both Terminal A and Company 3. The e-mail has no clear main addressee which causes confusion about who is responsible for the goods. Attached to the mail is a document, with information about basic product designation and quantity, which should be placed on the pallets. For the basic products manufactured and delivered with cage, the phosphating process is simple and preformed the same day; the order is sent by e-mail, the document is printed by Terminal A and sent together with at least a full pallet to Company 3. The pallet is transported to an elevator which takes the order up to Company 3, located in the same building as Terminal A.

The bundling process

For the 7 basic products designations manufactured without cage and bundled not to fall apart during the phosphating process, the process is unclear. For example it is unclear how the bundling process is initiated.

From Terminal A there is one daily transport to Unit 1 at 13:00-14:00 by truck. If an order reaches Terminal A after 13:00 it is sent the day after. The goods is first transported to terminal D1 and then to Unit 1 Production by elevator. There are lots of problems with the elevator which does not give any signal when it is loaded or unloaded, or when reaches the right floor. As the pallets arrive about 14:00 and as Unit 1 Production only work day shift which is finished at 16:00, the pallets are often delayed until the day after.

Table 18. Time spent on bundling in Unit 1 Production in 2011

Time spent on bundling basic products in Unit 1 Production 2011:
Lead time for bundling 1 designation with 4*CS, 2011:
C/O bundling: 120 sec/pallet, C/T bundling: 15 sec/product C/T administration: 120 sec/pallet, C/T cutting ties before final assembly: 5 sec/product Available work days in Unit 1 Production during a year for 1 operator: 45 weeks = 225 days.
Total lead time for bundling 2011 (4*3 clearance):
546156 sec **= 151,71 h (for 1 operator)** 151,71 h / 225 workdays per year = **0,67 h for 1 operator/workday 2011**

The bundling process has a cycle time of 15 seconds per product. It has a set-up time of 3 minutes per order for goods reception, transporting the pallet to the other unoccupied side of the site and preparing a second pallet for filling with the bundled products and getting bundle ties. The lead time for stacking the residual pallet after bundling and doing administration is 3 minutes per order where the phosphating order paper is printed and labeled on the pallet as well. Furthermore the lead time for cutting the loose the ties before final assembly of 5 seconds has to be taken into account as well. When bundling, 3-4 operators usually get together and bundle in parallel where a full pallet of 2000 products takes about 2 hours lead time. Table 18 shows the total time spent on bundling during 2011 in Unit 1 Production which was 151,7 hours, which is equal to 0,67 h per day for 1 operator. The data about the batch sizes from the factories is given in the document “Crosscheck partistorlek vs. rålager Product 2” and the sales statistics are taken from the ILR statistics for 2011. After bundling a paper is labeled on top of the pallet with information to Terminal A to send it directly for phosphating. All pallets are sent down to D1 by elevator at the end of the day at 16:00 which is too late to catch one of Company 1’s internal transports from D1 back to Terminal A. The bundled products reaches Terminal A by the first truck in the morning and are directly sent to Company 3. At the most, the bundling process has a total lead time of 4 days: Terminal A receive the order day 1 after 14:00, and the bundled products return to Terminal A day 4 in the morning.

The phosphating process

Company 3 is operating in 4 shifts. When a full pallet is received in the elevator the pallet is unpacked. The phosphating machine has 2 process options; larger products are hung on a rack while smaller products and shields are put in a tumbler. Often products are packed in a plastic bag in a full pallet from the factories, but it is easier for Company 3 to pour the products into the tumbler if they are packed in big packs (“kassetter”) instead. Both the racks and the tumbler are hung on 14 arms and are traveling through the machine’s 19 station baths, being dipped up and down between them to drain out, with 150 seconds processing time in each bath, before being put in metal boxes. The tumbler have exactly 6 seconds to drain out in the air over the last bath before crossing the wall over to the next bath. Unfortunately only one arm is currently working properly, which limits the capacity in the process for smaller products. The smaller products and shields, which are phosphated in the tumbler that rotates during operation in each bath, have the final drying process in an oven lying on a moving line. The large products on the racks are drying in the air during the last stations. When reaching the final station the larger products are picked from the racks and placed in metal boxes by hand and the quantity is controlled manually. The smaller products and shields are poured from the oven line into a metal box that is placed on a scale for controlling the quantity through the total weight. The shields are then lifted by hand from the metal box to be packed in a pallet while products are kept in the metal boxes. The processing time of traveling through the machine's 19 stations is 60 min. Since just 1 of the 14 arms can lift a tumbler the capacity is only 6 tumblers per shift while the capacity for the racks is 78 per shift. The tumbler can take between 100-200 products per process while 1 rack can take 16-23 products per process. After being put in metal boxes and bundled on pallets documents are printed and attached and the document from Terminal A that followed the pallet up is attached to the boxes before being sent down to Terminal A in the elevator. The total phosphating lead time is currently 2-4 days due to high capacity and low demand, but in the agreement with Company 1 Supply Chain the lead time is 5 days.

The repacking process

A full pallet sent to Company 3 for phosphating is sent back down to Terminal A in 3 metal boxes. The three metal boxes take up more space than one full pallet and cannot be placed in the warehouse racking. Directly when receiving the phosphated products from Company 3, Terminal A sends the metal boxes with the daily transport to Unit 1 Production for repacking into pallets. Since all parties concerned prefer not to repack, the products are sent for storage in the basement of D3. The products are registered in the system for Supply Chain, to see the availability and waiting for final assembly orders. Currently the space in the basement is full, meaning that Unit 1 Production is forced to repack the products into pallets, label the attached documents and send them back through D1 to be stored at Terminal A waiting for final assembly orders. The repacking process has a cycle time of 1 second per product and a set-up time of 3 minutes per order for goods reception, transporting all metal boxes to the other unoccupied side of the site and preparing a pallet for repacking. The lead time for bundling the empty metal boxes on pallets, stacking residual pallets and doing administration is 3 minutes per order. The total lead time for the repacking process, as it should be if no metal boxes were placed in the D3 basement, is shown in table 19. The data about the average batch size from the factories has been given by the document "Crosscheck partistorlek vs. rålager Product 2" and the sales statistics are taken from the ILR statistics for 2011.

Table 19. Time spent on repacking in Unit 1 Production in 2011

Time spent on repacking phosphated basic products in Unit 1 Production 2011:
Repacking lead time:
C/T repacking: 1 sec/product C/O repacking: 3 min/phosphated order C/T bundling metal cages on pallets and administration: 3 min/phosphated order
Total lead time for repacking 2011:
297265 sec = **82,6 h (for 1 operator)** 82,6 h / 225 workdays per year = **0,37 h for 1 operator/workday 2011**

In the worst case the repacking process has a total lead time of 4 days: Terminal A receive the metal boxes day 1 after 14:00, and the repacked products return to Terminal A day 4 in the morning. Since the ordering quantities from the factories are 1-13,5 batch sizes per basic product designation and that Terminal A only handle full pallet quantities, the result is that available in stock at Terminal A is a mix of both phosphated and non-phosphated products in quantities equivalent to 1-13,5 batch sizes per basic product designation. Supply Chain's ambition is to have only one batch size that should be phosphated.

Table 20. Second part in Product 2 product flow: phosphating basic products and shields

SUMMARY: Phosphating basic products and shields	
	Lead times:
	1. Bundling process (Terminal A → Unit 1 Production → Terminal A): 3-4 days - Total time spent on bundling in Unit 1 Production 2011: 0,67 h for 1 operator/workday 2. Phosphating at Company 3: 2-4 days (currently due to high capacity), 5 days (in the contract) 3. Repacking process (Terminal A → Unit 1 Production → Terminal A): 3-4 days - Total time spent on repacking in Unit 1 Production 2011: 0,37 h for 1 operator/workday
	Identified problems:
1.	No main addressee in the e-mails to Terminal A and Company 3 creates responsibility uncertainties.
1.	Uncertainties about how the bundling process is initiated.
2.	Both low availability of and low effectiveness in material transports in the elevator in D3.
3.	Bundling is a non-value adding and time consuming activity.
4.	Time consuming for Company 3 to put products in tumbler if packed in plastic bag in full pallet.
5.	Only 1 tumbler available at Company 3 limits the phosphating capacity for smaller products.
6.	Phosphated products in metal coxes cannot be placed in Terminal A's racking.
7.	Neither Company 3 nor Terminal A want to repack from metal boxes into pallets, leaving the repacking to Unit 1 Production.
8.	Repacking is a non-value adding and time consuming activity.
9.	Lots of material handlings and transportations are needed for bundling and repacking.

7.1.2.3. The third part: final assembly and delivery

The first customer ordering point for the Product 2 product flow is situated in the finished goods stock on Location A or Location B when a customer order is placed to an available product designation. The second customer ordering point is situated in the stocks of phosphated products and shields at warehouse Terminal A, graphite grease at D3 Basement and graphite components at the supplier.

Creating a production order

When Supply Chain receives either a production proposal from the system for a stock item or a customer order for a non-stock item, a production order is created. First Supply Chain reserves production capacity in the Unit 1 production lines for the customer order. The stated capacity for the production lines is 90-196 products per hour depending on the dimension of the product designation and a set-up time of 20 min. The production information is then copied and pasted into an excel file called "sekvenslistan" that Unit 1 Production is using for their daily production planning. The operators of Unit 1 Production experience large problems with this production planning. The production and packing of Product 1, 2 and 3, are separately booked using the same single production capacity in Supply Chain's system without having any booking limitations. There is no coordination between the capacity bookings of the three products and each of them have a separate excel file in "sekvenslistan" which put large demands on Unit 1 Production in their daily production planning. Their wish is to have a solution similar to what all the other production channels have at Company 1 with only one planning system with a limited capacity to simplify the production planning.

Ordering components for final assembly

When production capacity is booked, Supply Chain order phosphated products and shields from Terminal A in an e-mail or if available in D3 Basement Supply Chain writes in the "Sekvenslista" telling Unit 1 Production to pick from there. Graphite components are ordered from the supplier's finished goods stock. This procedure was recently changed from being done by fax, to be done through SIM. The phosphated products and shields are delivered on 1 day but the graphite orders have a lead time of 3-5 days until delivered at Unit 1 Production for final assembly. This longer lead time of 3-5 days is called the "M-lead time" and has been set to 6 days. It is the bottleneck that limits how fast the final assembly of an order can be started and also should be finished after receiving a customer order. This M-lead time is common for all 4 final variants even though item1 and item2 can be assembled on day 2 it has to wait 6 days for final assembly. The delivery lead time from the supplier was until recently 5-7 days but due to two changes it has been reduced to 3-5 days. The first change was to stop sending orders to the supplier by fax with 1 day of delay and instead create a direct connection through the program SIM which is now under implementation. Then all orders sent by Supply Chain are received directly by the supplier in e-mails. For urgent situations there is a possibility to order components by phone the same day as the shipment. Then the order must be phoned to the supplier before the truck leaves at 14:00. The second change was to redirect the shipments from the supplier to not be delivered Terminal A as before but to be delivered to D1 for direct transport to Unit 1 Production by the elevator. 2 shipments per week on Tuesdays and Thursdays are transporting graphite orders from the supplier to Unit 1 Production. The orders must as latest be delivered the day before the shipment to be picked and packed but with the old fax system with 1 day of delay the orders had to be sent 2 days before the shipment. The shipments from the supplier arrive at a hub at Location A the same evening and are delivered at Company 1 next morning. When being delivered to Terminal A, the orders were often delivered at D1 and Unit 1 Production 1 day later in spite the fact that the supplier's transport arrived at Company 1 in the morning and the daily transport from Terminal A to D1/D3 is shipped at 13:00-14:00. By redirecting the shipment to D1 directly the orders always are delivered on Wednesday and Friday mornings.

The final assembly process

After receiving both phosphated products and shields from Terminal A or D3 Basement, graphite components from the supplier or graphite grease from D3 Basement, the order is ready for final assembly at the latest on day 5. As pallets are received from Terminal A and D1/D3 at about 14:00 in the afternoon and Unit 1 Production ends its day shift at 16:00 it is often too late to start the order the same day. Therefore most orders are started and finished day 6 as the M-lead time is set to. If the order is urgent it is assembled directly otherwise it waits in the incoming buffer until next day. Unit 1 Production has 2 production lines; Line 1 for smaller dimensions with a capacity of 196 products per hour, and Line 2 for larger dimensions with a capacity of 96 products per hour. Both production lines consist of automatic machines and manual assembly stations connected by a moving conveyor belt. The Lines have set-up times of totally 20 min if all operators do the set-up simultaneously and often is next set-up of a station started when the last product has left the station. All cycle times and lead times are twice as long in Line 2 compared to Line 1 due to older machines and larger product dimensions.

Line 1 has 8 stations in total and the cycle time for each station is about 6 seconds, and the lead time for going through the entire production line is about 5 minutes. Only order quantities of over 100 products are assembled in the production lines. If the order quantity is less than 100 products they are assembled manually at a separate area in the production site. The stations in the 2 production lines are placed in the following order:

1. Assembly station for manually mounting graphite components and placing shields
The assembly station has 2 workstations where 2 operators simultaneously are mounting graphite crowns into item4, graphite segments into item3, and place shields on item2, item3 and item4. The products are then placed on the moving conveyor belt for travelling into the shield mounting machine.

2. Shield mounting machine
Dimensions in Line 1: 30-120 mm. Dimensions in Line 2: 30-200 mm. The shield mounting machine process 1 product at a time with a cycle time of 6 seconds, but it can only mount 1 shield on the upper side of the product. This means that the 3 variants that are having shields item2, item3 and item4 all have to go through this machine twice to be shield mounted on both sides.

3. Laser marking machine
Dimensions in Line 1: 30-190 mm. Dimensions in Line 2: 30-160 mm. Dimensions larger than 190 mm are marked manually through etching. The laser marking machine in Line 1 can mark both phosphated and non-phosphated products but the laser marking machine in Line 2 can only mark non-phosphated. This means that large phosphated product have to be picked off Line 2 after the shield mounting process to be laser marked in Line 1, then be picked off Line 1 to be packed in Line 2, because the laser marking and shield mounting machines for large dimensions are not placed in the same production line. The marked surface has to be clean, therefore is the laser marking performed before the grease filling.

4. Grease filling machine in Line 1, and manual grease filling in Line 2
The products are filled with the graphite grease from above. This gets problematic in the automatic Line 1 because the shields are also mounted on the upper side, making one operator having to turn all products upside down before entering into the grease filling machine.

5. Plastic machine
6. Packaging machine
7. Package labeling machine
8. Bundling machine

After the product packages have been bundled they are pushed out on a surface from where they are manually placed into a pallet.

Unit 1 has 4 final variants of Product 2, which each of the 50 basic product designations can be modified into: item1, item2, item3 and item4. Both the M-lead time and the final assembly process are different for each of these 4 final variants. The 4 last stations for the packaging procedure are used in the same way in a continuous flow for all the final variants, but the 4 first stations are used in different orders. Below is the final assembly process described for each of the 4 final variants in the assembly line 1 in Unit 1 Production.

Item 1
Item1 is based on phosphated basic products with cage from Terminal A and filled with graphite grease from D3 Basement. Its M-lead time is only 1 day waiting for the products to be delivered from

Terminal A to start assembling the order. Item1 has no shields, making it to the simplest final variant to assemble. The products are placed on the moving conveyor belt in front of the laser marking machine and then travels through laser marking, grease filling and all packaging stations for finally being placed in a pallet.

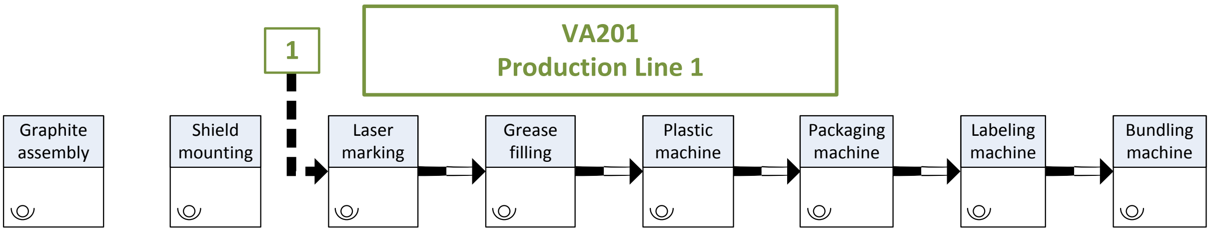

Figure 4. The material flow for item1 through the production line in Unit 1 Production

Item 2

item2 is the same grease filled final variant as item1, but with shields mounted. The process starts at the assembly station with an operator placing a shield on the upper side of the products and placing them on the conveyor belt in front of the shield mounting machine. Then the products travel through shield mounting and laser marking. Before reaching the grease filling machine, an operator turns the products upside down and places them on the conveyor belt with the shield down to enable the grease filling machine to fill from above. After being filled with grease the same operator picks the products off the conveyor belt onto a wagon. Then the whole batch is transported back to the assembly station to get a second shield placed on the product, and then sent into shield mounting machine to be mounted on the other side. Afterwards the products travel through the now inactivated laser marking and grease filling machines, and through all active packaging stations for finally being placed in a pallet.

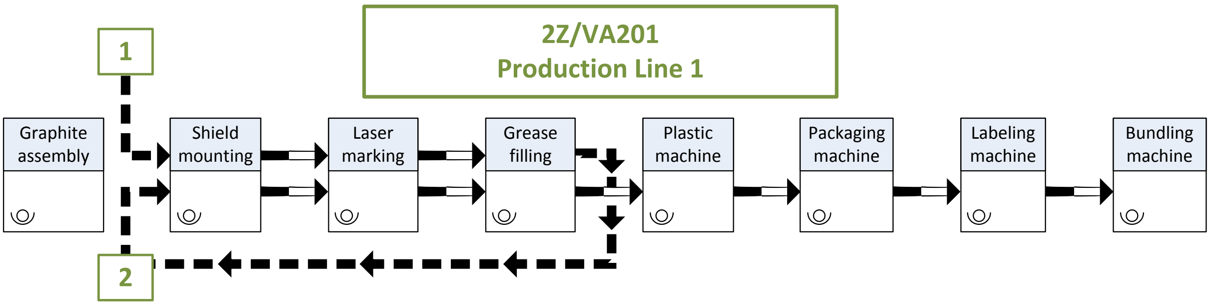

Figure 5. The material flow for item2 through the production line in Unit 1 Production

Item 3

Item3 is based on phosphated basic products without cage and with shields from Terminal A, and is mounted with graphite segments from the supplier. Its M-lead time is 6 days; waiting for the graphite segments to be delivered from the supplier to start assembling the order. For the designations which are not ordered without cage the cage is removed during the waiting time. The process starts at the assembly station with an operator placing a shield on the upper side of the products and placing them on the conveyor belt in front of the shield mounting machine. Then all products travel through shield mounting and are picked off the conveyor belt onto a wagon. The whole batch is transported back to the assembly station, the products are placed with the shield down, graphite segments are mounted in the products and a second shield is placed on the top. Then the products are placed on the conveyor belt and travel through shield mounting, laser marking, the now inactivated grease filling machine, and through all active packaging stations for finally being placed in a pallet.

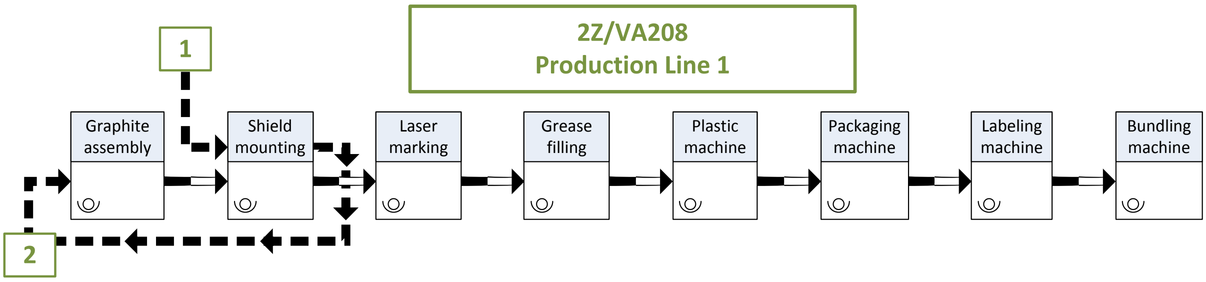

Figure 6. The material flow for item3 through the production line in Unit 1 Production

Item 4

Item4 is the same final variant as item3 but is mounted with a graphite crown instead of segments. The process starts at the assembly station with an operator mounting a crown in the product, placing a shield on the upper side of it, and placing it on the conveyor belt in front of the shield mounting machine. Then all products travel through shield mounting and are picked off the conveyor belt onto a wagon. The whole batch is transported back to the assembly station where a second shield is placed on the other side. Then the products are placed on the conveyor belt and travel through shield mounting, laser marking, the now inactivated grease filling machine, and through all active packaging stations for finally being placed in a pallet.

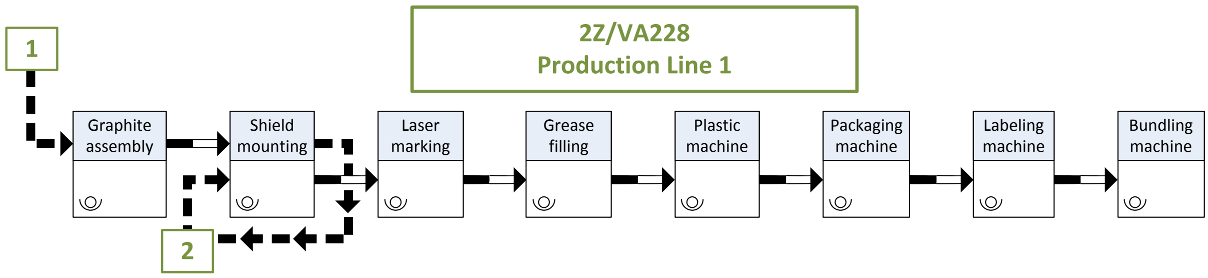

Figure 7. The material flow for item4 through the production line in Unit 1 Production

Mounting the graphite in the products takes the longest time with a cycle time of 20 seconds for segments and 10 seconds for a crown. Since 3 operators mount segments simultaneously the cycle times become 7 seconds per product. This is not an ideal solution since at the 2 assembly stations there are only 2 available work stations for operators to sit and mount. The third operator has to mount while standing up. For mounting the crown 2 operators are enough for reducing the cycle time from 10 seconds to 5 seconds per product, which is below the 6 seconds.

Out of the 4 final variants it is only item1 that has a continuous flow through the entire production line. The other 3 variants have first a batch production for the whole order quantity, where the rest of the downstream packing machines are standing still, until the second shield mounting starts. Then when the last product has been picked off the conveyor belt the second shield mounting starts and has a continuous flow through the entire production line. This procedure makes the shield mounting machines to the bottlenecks of each production line with lots of idle time in the production lines while waiting for the entire batch to be finished. In table 22 are today's lead times through the whole production Line 1 calculated for each final variant and compared to a continuous flow scenario.

After packing the bundled products into a pallet, WASS-labels are printed and labeled on the pallet. Then it is placed in a shipment buffer waiting to be sent to Location A through the elevator 28 together with all finished pallets at the end of the day at 16:00.

Table 21. Lead time through the production lines with and without double shield mounting

Lead time through the production line 1 due to double shield mounting:
Today's conditions for final assembly in Line 1:
Lead time through the production line: 5 min = 300 sec Cycle time: 6 sec Minimum order quantity: 100 products 8 stations = 7 traveling distances between the stations through the production line. The second shield mounting operation does not start until all products are picked off the line.
Today's lead times through Line 1 for the 4 final variants (order quantity = 100 products, disregarding set-up times):
Item1: (5/7)*300 + 99*6 = **808 sec** **Item2:** (2/7)*300 + 99*6 + (6/7)*300 + 99*6 = **1531 sec** **Item3:** 100*6 + (7/7)*300 + 99*6 = **1494 sec** **Item4:** (1/7)*300 + 99*6 + (6/7)*300 + 99*6 = **1488 sec**
Theoretical change of lead times through Line 1 if having continuous flows:
Item1: (5/7)*300 + 99*6 = 808 sec 808/808 = 1 **Item2:** (7/7)*300 + 99*6 = 808 sec 808/1531 = **– 48 %** **Item3:** (7/7)*300 + 99*6 = 808 sec 808/1494 = **– 46 %** **Item4:** (7/7)*300 + 99*6 = 808 sec 808/1488 = **– 46 %**

Goods handling at Location A

An elevator takes the pallets down to the basement where an operator from Location A is waiting for the shipment. Every day at 16:00 the operator drives his forklift to this elevator 28 in the basement of Location A for receiving the shipments. When Location A receives a shipment, they have 3 days to register it as available in the system "ready-for-picking" (RFP). As a comparison; IDW Location D only need 1 day for registering incoming shipments as RFP. For urgent orders Unit 1 Production label the pallet "Snabbinfackning" to indicate for Unit 1 Production to do the registration directly after receiving the pallet. This is an exception the standard lead time for registration as RFP is 3 days.

At urgent situation the Sales Unit's Customer Service or a Distributor place a sameday order in the system and Unit 1 Production requests "snabbinfackning" for getting as minimal lead time as possible through Location A. According to a Logistician at Location A, the lead time through Location A for a sameday order with requested "snabbinfackning" is as follows:

16:00: Order is picked up at elevator 28 from Unit 1 Production.
18:00: Registered as RFP if "snabbinfackning" is requested.
22:00: Order is picked by an operator.
23:00: Order travels through the conveyor belt for packing and labeling.
04:00: Order is loaded and shipped by night truck to Location B (2-5 transports/day).

When a product is registered as RFP, the standard time is 3 days for picking and shipping stock items, and 2 days for non-stock item. The lead time affecting the customers' order-to-delivery lead time, depends on which customer ordering point used and if a stock item or a non-stock item is ordered. The Product 2 product flow has 2 customer ordering points; the first is at Location A when ordering a product that is available in stock and registered as RFP, and the second is at Terminal A, D3 Basement and the graphite supplier when ordering components for final assembly. If the customer ordering point is at Location A and the ordered products is available in stock the lead time for picking and shipping is 3 days for a stock item and 2 days for a non-stock item. About 25 of the 151 non-stock items have actually the delivery strategy make-to-stock which makes 2 days picking time possible. It should be 3 days but these designations are not registered as stock items. If the customer ordering point is at Terminal A, D3 Basement and the graphite supplier the lead time through Location A is 5 days since they have 3 days for registering as RFP and 2 days for picking and shipping a non-stock item. Then the order is loaded to a truck for either refilling the finished goods stock on Location B which takes 1 day or for final transportation to the customer.

Total customer order-to-delivery lead time for Product 2

The total customer order-to-delivery lead time depends on if the ordered products have the delivery strategy of make-to-stock (MTS) or make-to-order (MTO). Designations having MTS: the order-to-delivery lead time for all 4 final variants is only 2-3 days for picking and shipping at Location A plus transportation time to the customer. Designations having MTO: the lead time is 6 days for all 4 final variants despite the fact that the delivery lead times for components for item1 and item2 is only 2 days from Terminal A. This is due to the system where a separation of the two would create problems.

Table 22. Third part in Product 2 product flow: final assembly and delivery

SUMMARY: Final assembly and delivery	
	M-lead times and total order-to-delivery lead times for the 4 final variants:
	Item1 and item2: M-lead time: 6 days (even though all components for final assembly can be delivered day 2). No cage removal performed. Double shield mounting performed for item2. Total order-to-delivery lead time: - MTO: 11 days + transportation time (even though orders can be finished in 8 days + transportation since all needed components are available in stock at Company 1). - MTS: 2-3 days (stock items: 3 days, non-stock items: 2 days) + transportation time. **Item3 and item4:** M-lead time: 6 days Cage removal and double shield mounting performed for both item3 and item4. Total order-to-delivery lead time: - MTO: 11 days + transportation time - MTS: 2-3 days (stock items: 3 days, non-stock items: 2 days) + transportation time. Total time spent on cage removal in Unit 1 Production 2011: 2,19 h for 1 operator/workday
	Identified problems:
1.	Operators work in different ways with different lead times in Unit 1 Production. No standardized work is applied.
2.	The laser marking and shield mounting machines for large dimensions are misplaced in lines.
3.	The laser marking machine in Line 2 cannot laser mark phosphated products.
4.	The double shield mounting operations result in longer lead times in the production lines. Lead times can be reduced with 46 % if achieving continuous flows.
5.	3 operators are needed for assembling item3 but only 2 workstations are available.
6.	5 days lead time for MTO-products for just travelling through Location A.
9.	Same M-lead time of 6 days for all 4 final variants, even though that item2 and item1 are delivered to Unit 1 Production and are ready for final assembly already day 2.

7.1.3. Are customers' needs fulfilled?

When comparing the current order to delivery lead times of Product2 with Unit 1's different customer's order-to-delivery lead time acceptances, it is shown that only 1 customer need of 3 is fully satisfied for all 200 product designations of Product 2.

1. For non-urgent needs, from EOMs, AMCs and Distributors, the order-to-delivery lead time acceptance was less than 4 weeks:
This is fulfilled by all 200 final designations which lead times are 2-11 days + transportation time.

2. For urgent needs from EOMs, AMCs and Distributors, the order-to-delivery lead time acceptance was 12 h – 2 days (simple products) or < 1 week (complicated products):
This only is fulfilled by the 49 + 25 designations having the delivery strategy make-to-stock which lead times are 1 day + transportation time if express orders using TNT are placed to Location A or Location B. This is not fulfilled by the remaining 126 designations having the delivery strategy make-to-order which lead times are 11 days + transportation time.

3. For new product interests from existing or new customers the order-to-delivery lead time acceptance was 1 week:
This only is fulfilled by the 49 + 25 designations having the delivery strategy make-to-stock which lead times are 2-3 days + transportation time. The needs are not fulfilled by the remaining 126 designation having the delivery strategy make-to-order which lead times are 11 days + transportation time. If the Business team has to be involved when receiving a new interest the total lead time is 4 weeks for a test product delivered through the make-to-order flow.

These comparisons are based on using the standard processes of the Product 2 product flow. If not using the standard process through Location A and instead using the different ways of reducing lead times that are offered by the current state flows already today the result is another. By using the combination of placing a sameday order at customer order entry, prioritizing in Unit 1 Production and requesting "snabbinfackning" at Location A for urgent situations; also the designations of item1 and item2 having a make-to-order delivery strategy fulfill the third customer need of new interests. With a M-lead time of 1 day and a production lead time of 1 day in Unit 1 Production, since the pallet is received 14:00 from D1/D3 just 2 hours before the shift ends, the finished order is sent to Location A in the elevator at 16:00 day 3. If Unit 1 Production requests "snabbinfackning" and it is a sameday order; the pallet is registered RFP and picked the same evening, and shipped in the morning day 4 according to the Logistician at Location A. Then the order got almost 2 full days available for transportation to be delivered at its customer in 1 week. That is a reasonable transportation time since a shipment from Location A to Location B takes 1 day.

For the designations item3 and item4, which have the make-to-order delivery strategy, it is not possible to achieve a total order-to-delivery lead time of 1 week. By using the combination of sameday order and "snabbinfackning" the lead times are reduced to 1 day at Location A. And by sending the orders to the graphite supplier by phone before 14:00 on the shipment day the M-lead time is as longest 4 days due to only two transportations per week. Since the shipments from the supplier are delivered to D1 in the morning, unlike the daily shipment from Terminal A, Unit 1 Production has almost a half day to assembly the order the same day. Then the order would be sent to Location A 16:00 day 4 and be shipped in the morning day 5. 2 days of transportation makes the total lead time 7 days for the Location A market and this is only the case if the orders are received by Supply Chain from customers before 14:00. Otherwise the total lead time is 8 days.

Table 23. The lead times of Product 2 compared to customer's needs

SUMMARY: The lead times of Product 2 compared to customers' needs		
	Customer need:	**Are the Product 2 designations fulfilling customers' needs?**
1.	Non-urgent needs: < 4 weeks	The 49 + 25 stock items: Yes The 126 non-stock items: Yes
2.	Urgent needs: 12 h - 2 days, < 1 week	The 49 + 25 stock items: Yes, if placing express orders to Location B or Location A. The 126 non-stock items: No
3.	New interests: 1 week	The 49 + 25 stock items: Yes The 126 non-stock items: No (possible for item1 and item2)

7.2. Analysis

This section describes the analysis of the current system, what customer needs Unit 1 should focus on based on the conditions for their processes and what problems that are identified that stops Unit 1 from fulfilling the focus needs in the current process flows.

7.2.1. Focus needs

In order to fulfill all three customer needs a make-to-stock strategy for all 200 final designations is preferable. Such a strategy would however increase both stock levels and the amounts of tied-up capital for Unit 1. Due to the current situation within Company 1 with large pressure on decreasing stock levels and work in progress such total make-to-stock strategy is not possible to implement at the time of the study.

Since urgent needs of 12 h – 2 days can only be fulfilled by having a total make-to-stock strategy for all 200 designations this category has to be given up for the make-to-order designations. Today it is the responsibility of the Distributors to supply products to customers with urgent needs from their own stock. Either customers have a stock of safety products themselves or they make an agreement with a distributor to keep the stock for them. By having maintenance periods, to which they order products with non-urgent needs, customers can prevent urgent needs from arising in their production.

The non-urgent needs and new interests are most reasonable to fulfill for the Product 2 product flow. According the Business Engineer at Food and Beverage segment in Company 1 UK; these two categories are the most important to focus on. To be able to deliver products for testing rapidly when having new interests, and then deliver larger quantities with more reasonable lead times for implementation. This mix of short and long lead times is the only setup that gives an ability to increase sales to new customers.

The future focus should be to strive for fulfilling non-urgent needs and new interests. Non-urgent needs are fulfilled for all 200 final designations already today with order-to-delivery lead times of 2-11 days + transportation time. New interests are fulfilled by all make-to-stock designations. By using a combination of prioritizing in Unit 1 Production, placing sameday orders and requesting "snabbinfackning" at Location A; already today Unit 1 is able to fulfill new interests for also all the make-to-order designations of item1 and item2. For item3 and item4 these combinations are not enough for fulfilling the need of new interests for all designations. By focusing on developing a product flow with an order-to-delivery lead time of 1 week that fulfills this customer need also for all the designations of item3 and item4 Unit 1 is able to increase sales even more by reaching new customers with all 200 designations.

7.2.2. Problems of fulfilling the focus needs in the current system

Several problems preventing Unit 1 from fulfilling the needs of new interests for the two final variants of item3 and item4 are identified. These identified problems can be divided into two categories; direct lead time related problems and indirect lead time related problems. The first category consists of processes and activities after the customer ordering point with long lead times that exceed what can be acceptable to be able to deliver test products within 1 week. The second category consists of capacity related problems that limits the performance in the process flow. It primarily concerns the non-value adding processes and activities, both prior and after the customer ordering point, consuming capacity from Unit 1 Production. This consumed capacity is taken from the common capacity of Unit 1 Production that could have been used for finalizing orders instead of performing non-value adding work. The indirect lead time related problems therefore risk increasing lead times and creating internal queues when capacity needs to be dedicated to non-value adding work instead of finalizing customer orders.

7.2.2.1. Direct lead time related problems

To be able to achieve a total order-to-delivery lead time of 5 days sameday orders, "snabbinfackning" and prioritization in Unit 1 Production is used. The final assembly and packing processes must be finished in Unit 1 Production on the end of day 3. Today customers' orders on item3 and item4, which in worst case have a delivery lead time from the graphite supplier of 5 days, will at its best be shipped day 6 from Location A. With 2 days for transportation the order will be delivered to a customer on the Location A market day 8. When analyzing the make-to-order process flow of item3 and item4 mainly 5 problems are identified that limit these designations from being finished day 3 in Unit 1 Production.

The Business team

The Business team is mostly consulted when receiving new interests from customers. As the lead time for fulfilling the needs at new interests is up to 1 week and the Business team has lead time of 5-9 days the total lead time is 3 weeks. The process time for each of the 4 Business Team members is 1 day, the accepted lead time is exceeded.

The lead time for non-stock items through Location A of 5 days

Location A has 3 days to register an order as RFP and 2 days for picking and shipping order of non-stock items. That makes it impossible to have a make-to-order strategy for fulfilling this demand if only using official standard ways of working. For comparison does Company 1 IDW Location D only need 1 day for registering incoming goods as RFP.

The order-to-delivery lead time of graphite components of 3-5 days

Graphite ordering is the current bottle neck of the final assembly and delivery process at Unit 1 Production. Today the phosphated products and shields are kept in the goods reception buffer for the graphite components to be delivered from the supplier to start the final assembly process. As Unit 1 Production must have finished and sent the orders to Location A at the end of day 3; having an M-lead time of 6 days is unacceptable. Even the actual 3-5 days is too long for a fast flow.

The cage removal process of 3 days

The process is needed for the phosphated basic products that are not ordered without cage from Company 1's factories. The cage removal process has a lead time of 3 days and is today executed while waiting for the graphite components to arrive from supplier. As Unit 1 Production must have finished the orders and sent them to Location A at the end of day 3; having a delivery lead time from Terminal A of 1 day and a process lead time of 3 days is unacceptable.

The daily transport from Terminal A

As orders sent by Supply Chain day 1, arrives with the daily transport at 13:00-14:00 to D1/D3 day 2; Unit 1 Production only gets 2-3 hours + 1 day to finish the orders to be able to send it to Location A day 3. If having an already high work load in the production it will be stressful to enable finishing the orders before 16:00 next day. The more available time for the production the better and since orders sent to Terminal A day 1 is shipped day 2 an earlier daily transport day 2 would still give Terminal A 1 day to pick and load.

7.2.2.2. Indirect lead time related problems

When analyzing the three parts and the total flow as a whole several problems affecting the capacity in the Product 2 product flow are identified. This is the case especially at Unit 1 Production, Terminal A and D1 where comsiderable non-value adding activities are performed. The major activities and limiting conditions that consumes the operators available work time are following:

The repacking process

Due to the fact that Company 3 pack the products in metal boxes after phosphating, and that there is no equipment or space for repacking the products into pallets at Terminal A or at Company 3, the repacking is done at Unit 1 Production. The standard procedure today is that after phosphating the metal boxes are sent to Unit 1 Production for repacking into pallets. Then the pallets are returned to Terminal A for storage, to be available for final assembly orders. This procedure is not followed however. Instead of repacking Unit 1 Production sends the metal boxes to be stored at D3 Basement but the available space is currently full which forces Unit 1 Production to start repacking according to the process. If they would strictly follow the standard process of repacking; 1 operator would spend 82,6 hours per year on repacking. That is equal to 20 min per workday for 1 operator, calculated on 225 working days per year, according to the sales statistics of Product 2 year 2011 and the lead time of the repacking process. In addition operators at both D1 and Terminal A spend time on material handling activities when transporting the metal boxes and pallets back and forth.

The double shield mounting operation

Due to that the shield mounting machines in the production lines in Unit 1 Production only can mount 1 shield on the products all products of item2, item3 and item4 have to go through that operation twice. It is only item1 with no shields that has a continuous flow through the production lines. Based on the lead time through the whole production line and the cycle times of its operations; the total lead times through the production lines for item3 and item4 can be decreased with 46 % if being able to create continuous flows for these 2 final variants when eliminating the idle time in the production lines.

7.3. Proposals for an improved future system

This section describes the objectives for the future state flows and which improvements that are necessary for achieving them and fulfilling the focus customer needs.

7.3.1. Objectives for the future state flows

The focus for Unit 1 is to fulfill non-urgent needs and needs of new interests for all 200 final Product 2 designations. That is already accomplished for non-urgent needs but not for new interests. The only designations that currently do not fulfill needs of new interests are the final variants of item3 and item4. Therefore the objectives of the improvements proposals for the future state process flow of Product 2 is to develop conditions for also these 2 final variants to be successful.

The proposals aim to create 2 flows; one fast process flow for customer orders of new interests, and one standard process flow for customer orders of non-urgent needs. The standard flow fulfills the order-to-delivery lead time demand of 4 weeks already today with its 2-11 days + transportation time. The order-to-delivery lead time for the fast flow needs to be reduced from today's 8 days to 5 days. When counting backwards 2 days are dedicated for transport to customer, meaning the transport is shipped from Location A in the early morning day 4. By using the shortest alternative through Location A used today it takes 1 day through, meaning that Unit 1 Production has to finish the order and send it to Location A at 16:00 on day 3. If having a delivery lead time of basic products and graphite of 1 day, Unit 1 Production have 2 days to finish the orders, meaning that products and graphite is ordered day 1, delivered early day 2 and finished day 3 at 16:00.

When creating the fast flow for item3 and item4 the improvement proposals also aim to eliminate both the direct lead time related problems and the indirect lead time related problems which today stops the fast flow from reaching 5 days and risk creating lead time increasing material queues in Unit 1 Production.

7.3.2. Improvement proposals for the future state process flows

Following improvement proposals will achieve a fast flow for the two final variants item3 and item4, with a total order-to-delivery lead time of 5 days, for fulfilling needs of new interests.

7.3.2.1. Reduce the lead time for the Business team to 1 day

The Business Team is mostly needed when orders are placed of customers with new interests. If Unit 1 were able to deliver a test product in 1 week only 1 day for the Business team can be accepted and this day is taken from Unit 1 Productions 2 days. One way to decrease the lead time in the Business Team is to have a parallel process where each of the 4 persons involved investigate their own parts simultaneously. Then the theoretical lead time is 1 day. Another way is to move investigation if certain aspects, such as packing, to be perform and solve those problems after hand.

7.3.2.2. Decrease the lead time of graphite components from 3-5 days to 1 day

Today the order-to-delivery lead time from the graphite supplier is as shortest 3 days. To be able to be finished with an order at the end of day 3 the graphite components must be delivered to Unit 1 Production during early day 2. Today there are 2 shipments per week and the supplier wants to receive the orders 1 day before the shipment. Even if the orders can be sent the same day as the shipment it will only be delivered in 1 day if the customer order is received and sent to the supplier on Tuesdays and Thursdays. One option is to increase the number of shipments per week to Company 1 or to external express shipments with TNT when receiving orders of new interests. This solution is costly, since the order quantity for new interests is between 1-10 products which make the transport cost per product very high.

A proposal that provide instant availability of graphite components, beneficial for all designations, is to have all the finished goods stock of graphite components in one of Company 1's warehouses at Location A. This enables instant deliveries and the high availability can be used for all orders, not just for fulfilling new interests. The new M-lead time of 2 days enables a fast flow, lower stock levels at Location A and Location B of Product 2 stock items, since the replenishment lead time is shorter which enables ordering more frequently. When having the stock at Company 1; one of the two transports from the supplier per week that Unit 1 pays for can be eliminated, to only have one transport per week for refilling the stock.

If not moving the whole stock of graphite to Location A; do it just for non-stock items

If not being able to take advantage of the instant availability of graphite components for lowering the stock levels for finished goods, it is unnecessary to have the graphite stock at Location A for stock items. Because these final designations are ordered from finished goods stock, so if the delivery lead time of graphite is 5 days longer does not affect the lead time to the customer since this happens before the customer ordering point. For non-stock items the customer ordering point is before the graphite is delivered to final assembly affecting the lead time to customer. Therefore it is more important that non-stock items have graphite available at Location A to enable deliveries in 2 days.

If not moving the whole stock of graphite to Location A; keep all stock at the supplier and make item3 and item4 to stock items, and item2 and item1 to non-stock items

Another option is to keep all stock of graphite at the supplier with 3-5 days delivery lead time and make all designations using these components as stock items. Of the same reasons as mentioned above, as all components for item1 and item2 are available at Location A with 1 day lead time, therefore it is unnecessary to have these two final variants as stock items. It is more important to have item3 and item4 as stock items, both due to the longer delivery lead time from the supplier but also due to that these two final variants are more expensive to customers. If having a better availability of these 2 variants, Unit 1 can affect customers to buy a more expensive product.

7.3.2.3. Eliminate the bundling and double shield mounting processes by ordering right products from the beginning from the factories

Order basic products without cage with 1 shield mounted

The great majority of basic product designation manufactured without cage falls apart according to an investigation done by a Development Engineer at Unit 1. When ordering basic products that already have fallen apart in the pallet during transportation the lead time of the bundling process becomes much longer when the products have to be assembled before they can be bundled.

One way to eliminate the problem with the time consuming bundling process that also solves the problems with the 46 % idle time in the production lines is to mount 1 shield on one side of all basic products without cage. The single shield keeps the inner ring of the product centered and prevents it from falling apart which eliminates the need of bundling before phosphating. As 1 shield already is mounted it also eliminates the need of double shield mounting in the production lines which enables lead time reductions in the production lines of 46 %. The negative aspect with having 1 shield mounted on is that it makes the assembly of the graphite crown in item4 more difficult. Today it takes 10 seconds to assemble a graphite crown by placing the product onto the crown in the hand and adjust the balls to fit in each gap while observing and controlling from above. This method cannot be used with 1 shield mounted on. Instead the assembly would be exactly as for the segments in item3 where the first shield is mounted before doing the assembly. Then by using a stick the balls are adjusted aside when mounting the segments with a cycle time of 20 seconds per product. This means that the assembly time will be doubled for item4 but unchanged for item3. If being able to develop a fixture for spreading the balls into right places before assembling the crown much is gained. For example today 3 operators are used for assembling item3 in order to get a cycle time of 7 sec instead of 20. If being able to reduce the cycle time to 14 sec by using a fixture only 2 operators are needed.

Experiment confirmed the disintegration preventing effect of 1 shield mounted on

The solution of 1 shield mounted was first questioned ad Unit 1, because 1 shield may not prevent the product from falling apart. To verify this proposal an experiment was performed. In cooperation with two Development Engineers at Unit 1, a product designation with a high risk probability of falling apart compared to other designations of 37 % was chosen. One operator at Unit 1 Production performed the cage removal and mounted 1 shield manually on each of 5 products. The products were exposed to force trying to part the rings. During the test, all products were held together by one shield. The conclusion of the experiment is that 1 mounted shield on one side of the product fully holds the product together, even when exposed to violence, for risk probabilities of 37 % and less.

Persuade Company 3 to phosphate products with 1 shield mounted

To be able to order basic products without cage and with 1 shield; the products must also be phosphated at Company 3 with 1 shield mounted. At Company 3, they saw two reasons not to accept the idea: The first concern was that the phosphating liquid, that fills the products when being dipped into, and processed in, the several baths, will not drain out of the products before going into the next bath. This would according to Company 3 damage their processes and liquid qualities since liquid from the first batch is transferred into next bath and so on. The second concern was that it also would damage the phosphating results of the products since remaining liquid from bath 1 stops the new liquid in bath 2 to from getting access to the products surface.

An experiment was conducted to verify the concerns. In cooperation with the Development Engineers at Unit 1, 5 products of a designation that already had been mounted with 1 single shield on each was sent to phosphating at Company 3. In accordance with their instructions the operator at Company 3 was told to phosphate these 5 products under as realistic circumstances as possible in a tumbler. He phosphated them together with other products in a tumbler and did not place them in a certain way. During operation the tumbler rotates in the bath to make the liquids reach all surfaces. After receiving the phosphated products both Development Engineers at Unit 1 investigated the phosphating result of all 5 and approved it as acceptable.

The second concern was that the 1 mounted shield on would damage their process and liquid qualities, since the mounted shield stops previous liquid from drain out of the product before being dipped into next bath. In order to verify the second concern a second experiment was performed in Unit 1 Production to test how much more liquid there is in a product with 1 shield compared to a product without shields after drain out in 6 seconds. According to the operator at Company 3 the liquid in the first bath “avfettningen” is the most viscous and the time for drain out is 6 seconds before entering the air over next batch. The measured drain out time of 6 seconds is from when the lowest part of the “tumbler” has crossed the liquid surface in the bath until it has crossed the wall into the air over the next bath. In order to achieve similar drain out conditions and due to time constrains of not being able to get a real liquid sample from Company 3 the liquid from Unit 1 Production’s washing machine was used. Then 3 products with 1 shield and 3 products without shields was dipped into the liquid, lifted up to drain for 6 seconds, and then placed on a scale. The products were held in 3 different angles during the drain out; horizontal, vertical and 45 degrees. The weights of the product were measured before being dipped and after being dipped. The results show that a vertical drain out has the smallest amounts of remaining liquid wiht about 4,7-16 % more than without cage. The second best was a horizontal drain out with 34-76 % more remaining liquid and the worst was 45 degree drain out with 63-105 % more remaining liquid than without a shield.

If not ordering products without cage with 1 shield; mount 1 shield manually instead of bundling

As 1 shield prevents the products from falling apart a manual shield mounting process should replace the bundling process before phosphating that is performed today. The bundling process is non-value adding and has a cycle time of 15 seconds per product, but manual shield mounting is value-adding and has a cycle time of only 6 seconds per products. Furthermore it is an operation that shall be done during final assembly and when 1 shield then already is prepared the 46% idle time due to double shield mounting can be eliminated.

7.3.2.3. Decrease the lead time through Location A from 5 days to 12 hours

The long lead time for non-stock items through Location A of 5 days, is already today solved by using sameday orders and “snabbinfackning”. According to the earlier mentioned example a pallet labeled with “snabbinfackning” and received by Location A at 16:00 day 3 is shipped in the early morning day 4, resulting in almost 2 days for transport to customer. When a Company 1 Sales Unit’s Customer Service or a Distributor receives a customer order, they must register it in the system as a sameday order. By doing so they ensure that the order is picked and shipped within 24 hours after the order is registered as RFP. To ensure that the order is registered RFP as fast as possible, to be picked as fast as possible, Unit 1 Production should label the urgent order pallets with a paper signed “snabbinfackning”. According to the Logistician at Location A this is no problem since the volumes sent from Unit 1 Production are low compared to the total volumes received from the rest of Company 1 Production.

7.3.2.5. Send the daily transport from Terminal A earlier to D1/D3

The daily transport from Terminal A that arrives at 13:00-14:00 to D1 and D3, gives Unit 1 Production only 2-3 hours plus 1 day to finish the orders the same day. Even if having a fast cage removal process, it is still stressful for all of Unit 1’s 4 final variants if already having a high work load in the production. If changing the daily shipment time to early morning Unit 1 Production would get almost 2 whole days for finalizing the orders. Already today there are orders sent to Terminal A, of phosphated products and shields, that are received too late to be picked and sent with the daily transport. In worst case; an order sent by Supply Chain to Terminal A day 1 after 13:00, will be sent with the daily transport during day 2. So by changing the shipment time from Terminal A to be as early as possible in the morning, orders sent during day 1 will always be delivered during day 2. This is acceptable if they are sent as early as possible, giving Unit 1 Production a whole workday to finish the final assembly.

7.3.2.2. Eliminate the repacking process by doing right from the beginning at Company 3

In order to eliminate the problem with the time consuming repacking process Company 3 must pack the phosphated products into pallets directly after the phosphating process. Company 3 today uses 2 types of product handlers in the phosphating process; racks and a tumbler. The racks are for larger products which the operator threads onto to the racks by hand. The tumbler is for smaller products and shields which are poured by the operator into the tumbler by hand. After the phosphating process; the products on the racks are picked off the racks by hand and placed in metal boxes and the operator are counting the quantity in his head. It would be no difference at all if the operator instead would place the products in a pallet since they are picked off by hand. The best alternative for eliminating repacking of product phosphated in the tumbler is to, instead of a metal box, place a pallet on top of the scale below the moving line and pour the products directly into the pallet. Company 3 reject this idea since there is not space enough for placing a pallet. Another alternative is to pour the products into a metal box and then afterwards empty the metal box into a pallet with some kind of lifting equipment. This is already the case for the shields, which the operators place in a pallet after being poured in a metal box. The shields are easier to handle than the products, since they are tied together in ropes which can be used for lifting by hand.

7.3.3. Expected results

All together these improvement proposals enable for all Product 2 designations to fulfill both non-urgent needs and new interests. By having phosphated products and shields and graphite components at Company 1's warehouses, and by having the daily transport from Terminal A to be shipped in the morning; orders placed day 1 are delivered in the morning day 2 and Unit 1 Production should be able to finish orders of 1-10 products during next day to be sent to Location A at 16:00 day 3. The combination of "snabbinfackning" and placed sameday order make the orders to be shipped in the morning day 4. Then there are almost 2 days of transports available to deliver the order in 5 days. These improvements will not only be of advantage for the new interests. By having all graphite components at Location A the shorter lead times of the make-to-order product flows also result in shorter replenishment lead times which enable lower stock levels and offer even the possibilities to reduce the number of stock items. This tied-up capital from lowering the needed safety stocks on Location A and Location B can be used to finance the stock build-up of graphite components at Company 1.

The great majority of the basic products without cage fall apart. By ordering 1 shield to be mounted on one side of the products the risk of falling apart and the bundle process is eliminated. Furthermore 1 shield is already mounted on the products which eliminate the need of double shield mounting. That enables a continuous flow through the production line with lead time reductions of 46 % for item3 and item4 which increases the productions lines capacity with 81 % for these 2 final variants. A fixture should be developed for reducing the assembly times of item3 and item4. If 1 shield is mounted at the supplying factories, the cycle time for assembling a graphite crown will increase to be the same as for assembling graphite segments. If a fixture could be developed that reduces the assembly times from 20 to 14 seconds it also reduces the needed operators from 3 to 2.

By having a divided stock of phosphated products and shields at Terminal A, consisting of both products with cage, and also products without cage and with 1 shield mounted on for each designation, it is suitable for all final designations. Especially since this stock of products in the future will be shared with Product 3. The products with cage and without shields are suitable for item1, item2 and the entire range of Product 3. The products without cage and with 1 shield are suitable for item3 and item4. To be able to have this mixed stock of 2 categories it is essential that the factories allow ordering in lower quantities since this mix require twice as much available space at Terminal A.

In 2011, 1 operator spent 0,67 hours per day on bundling, 0,37 hours per day on repacking and 2,19 hours per day on cage removal in Unit 1. By implementing all proposed improvements, 3,23 hours of non-value adding work per day for 1 operator in Unit 1 Production, is eliminated and can be used for value-adding work instead. By combining these capacity increasing improvements with the lead time reducing improvements Unit 1s ability to fulfill both non-urgent needs and new interests gets even better since no cage removal process is needed at all. The increased capacity in Unit 1 Production is necessary since Unit 1 has great expectation for Product 3 to grow on the market. Since Product 2 and Product 3 share the same production line for laser marking and packing the lead time reductions of 46 % due to eliminated double shield mounting will be valuable as well.

Table 24. PRODUCT 2 improvements for fulfilling the lead time demands of all new interests

SUMMARY: Improvements for fulfilling the lead time demands of all new interests	
	Improvements for the make-to-order product flow of item3 and item4: - To achieve a total order-to-delivery lead time of 5 days. - To ensure that Unit 1 Production can finish and send the order to Location A at the end of day 3. **Improvements for increasing production capacity and prevent internal queues** - To eliminate the non-value adding and time consuming repacking process. - To eliminate the non-value adding and time consuming cage removal process. - To eliminate the non-value adding and time consuming bundling process. - To increase the capacity in the production lines by eliminating idle time.
1.	Persuade the factories to allow lower minimum order quantities equal to 1 batch size. This increases the available storage space at Terminal A and enables ordering of more designations without cage.
2.	Persuade Company 3 to phosphate products with 1 shield mounted, and to pack products directly in pallets. The repacking process and material handling at D1 and Terminal A would be eliminated.
3.	Order basic products without cage with 1 shield mounted on one side to eliminate the cage removal process. The single shield prevents the product from falling apart which eliminates the bundling process. The single shield also eliminates the double shield mounting process and 46 % idle time in the production lines since 1 shield is already mounted in advance.
4.	When receiving a customer order for a new interest; Company 1 Sales Unit's Customer Service and the Distributors must register the order as a sameday order in the system. This in order to ensure picking and shipping within 12 hours from when the order has been registered RFP.
5.	When Unit 1 Production sends the finished order to Location A the pallet must be labeled on top with a paper signed "snabbinfackning". This is on order to ensure that the pallets is registered RFP directly after goods receipt at Location A on day 3.
6.	The finished goods stock of graphite components should be located at Company 1, in order to reduce the delivery lead time from 3-5 days to 1 day. This in order to enable for Unit 1 Production to send finished orders to Location A on day 3.
7.	The lead time for the cage removal process must be reduced from 3 to 1 day in order to enable for Unit 1 Production to send finished orders to Location A on day 3. Either by investing in a small oven or use one of the ovens assigned for reducing the drying lead time after washing for Product 3. Or by replacing the washing and drying processes with blowing the products clean by using high pressure air.
8.	The shipment time for the daily transport from Terminal A to D1/D3 must be changed from 13:00-14:00 to as early as possible in the morning. This ensure that all phosphated products and shields ordered day 1 is delivered to Unit 1 Production in the morning day 2, giving them 2 whole days to finish the cage removal and final assembly processes. This in order to enable for Unit 1 Production to send finished orders to Location A on day 3.
9.	The lead time for the Business team must be reduced to 1 day by using a parallel process instead of today's serial process. Also certain aspects such as packing can be investigated after hand.

8. The Product 3 product flow

This chapter describes the current state of the Product 3 product flow, with the delivery strategies and order handling procedures. The problems in the product flow are identified, and improvements are proposed with the intention to meet customer needs.

8.1. Description of the current system

This section describes the delivery strategy and current state process flow of Product 3, from a customer order is received until the order is shipped from Location A to Location B, a distributor or a final customer.

8.1.1. The delivery strategy for Product 3

Product 3 is rather new on the market, with currently low sales volumes compared to Product 1 and Product 2. Product 3 is based on 2 sorts of basic product. Firstly; 1-3 clearance products, from almost the entire range of Company 1's thousands of designations, available as finished goods products on stock in Company 1's. Secondly; 4*3 special clearance products are made-to-order for Unit 1 in Company 1's manufacturing factories. The 4*3 special clearance products are the same basic products used for Product 2, meaning that Product 2 and Product 3 share the same stock of phosphated basic products at Terminal A, with only a few exceptions.

Product 3 can be ordered from any of Company 1 thousands of designations for 1-3 clearance and any of the 50 basic product designations for 4*3 special clearances. In addition, Product 3 is a rather new product with low sales volumes and yet has no high runner designations been identified. Due to this, a delivery strategy of make-to-order is chosen to supply Unit 1's global customers. Since it is next to impossible to predict the customers demand, no 1-3 basic products are kept on stock at Location A, all 1-3 basic products are ordered from either Location B or the distribution center for the American market IDW Location F. These two warehouses have similar product designations in stock with similar availability. As the 4*3 only concern 50 basic product designations, with long production lead times from the factories of up to 40 days, all basic products are kept phosphated on stock at Location A available for final assembly. As Product 3, at the time of the study, exclusively is filled at a facility at Location F, basic 1-3 products are primarily ordered from Location F to minimize the lead time. After being filled, the products are shipped with air freight to Location A for laser marking and packing in Unit 1 Production. If there are no 1-3 products are available in Location F, or a customer has ordered a designation that require 4*3 clearance, basic products are shipped from Location A to Location F and back. The order-to-delivery lead times vary depending on where the basic products are ordered from. If ordered from Location B or Location A; the order-to-delivery lead time is 10-12 weeks. If the basic products are ordered from Location F, the order-to-delivery lead time is 7-8 weeks.

Table 25. Delivery strategy and product availability for Product 3

SUMMARY: Delivery strategy and product availability for Product 3		
Delivery strategy for Product 3		
Make-to-stock: due to unpredictable customer demand when being based on almost any of Company 1's thousands of 1-3 designations, and 50 designations of 4*3.		
	Basic product clearance	**Ordering warehouse**
1.	1-3 clearance	- Primarily Location F - Secondarily Location B and Location A
2.	4*3 special clearance	Terminal A

Unit 1 have high expectations for Product 3 to grow and take market shares both when used in similar applications as for Product 2, and by opening up new market areas. Unit 1 has perceived that customers often experience the order-to-delivery lead times of 7-12 weeks to be too long, compared to the lead times for other products offered by Company 1 and their competitors.

8.1.2. The current Location F process flow of Product 3

The make-to-order product flow of Product 3 consists of the processes of ordering basic products from IDW Location F, Location B, Location A or Terminal A; sending them to Unit 1 Production for repacking; shipping to the facility at Location F for filling; shipping them to Location A for packing at Unit 1 Production; and sending them to Location A for final delivery to customers.

8.1.2.1. Ordering of basic products and creating an order

After receiving a customer order in the system, Supply Chain checks availability of basic products. If the customer orders a 4*3 product; Supply Chain order its basic products from the phosphated stock at Terminal A. If the customer orders a 1-3 product; Supply Chain primarily checks availability on IDW Location F to reduce transportation lead times and costs, secondarily on Location A for large product in 2-3 manufactured in the Location A factory, and for remaining products on Location B. As all products are filled at Location F; the warehouse most convenient to use for 1-3 is located at Location F. If no products are available; basic products from either Location A or Location B are flown to Location F by air freight from Location A to Location F. According to a Supply Chain Manager at Unit 1, about 70 % of the basic products are ordered from Location F and 30 % from Location B, Location A and Terminal A. The availability of basic products is good in all warehouses for 1 clearance but worse for 2 and 3 clearances. In 10-20 % of the cases there is no availability of basic products, having to wait 2-6 weeks for next planned production period in the factories. When ordering basic products NN writes the delivery information in separate Google documents to certain Companies, in order to follow the shipments and informing the receivers of what to expect. Then packing is booked in the system in Unit 1 Production and the information is written in the "Sekvenslista" for production planning. When creating an order NN calculates with 2 weeks shipment from Location A to Location F, 2 weeks for filling at the facility, 2 weeks for shipment from the facility to Terminal A, and 2 weeks for packing at Unit 1 Production to have a safety lead time. After ordering basic products NN creates a series of documents for the order.

1. A purchasing order is created and sent by e-mail to the facility.
2. Based on the purchasing order, a waybill and a delivery note is created.
3. a shipping document for booking air freight is created.
4. The waybill and the shipping document are sent by e-mail to NN, Supply Chain Manager on Location A, Terminal 10, for booking a pick up and air freight with Airline A to the facility.
5. A list of the next incoming orders of basic products that are to be repacked before being sent to Location F. Orders that are consolidated are sent together. Unit 1 Production is told not to await orders for more than a week for consolidating. The reason for 5 days consolidation is not economical but rather an ambition of having efficient shipments.

Finally the list, the waybill and the delivery note are printed and given to the operators in Unit 1 Production.

8.1.2.2. Transport of basic products to Unit 1 Production for repacking

All products ordered from Location B, Location A or Terminal A have different transport routes to get to Unit 1 Production before being flown by air freight to Location F. The products ordered from Location A on day 1 are picked and transported to D1 by forklift on day 3 for transportation to Unit 1 Production by elevator on the same day. The products ordered from Terminal A on day 1 are delivered with the daily transport to D1 or D3 at 13:00-14:00 on day 2, for transportation to Unit 1

Production by elevator on the same day. The products ordered from Location B are transported on a detour before reaching Unit 1 Production. All basic products ordered from Location B for Product 3, are transported the same way as basic products ordered from Location B for Product 1. The products ordered from Location B day 1, are delivered to the Hub in Arendal day 3 awaiting transport to Company 2. In the worst case, it arrives to the Hub on a Friday day 3 and has to wait until Tuesday day 5 for transport. At Company 2, the order is received and sent back to Unit 1 Production with next transport. In the worst case the order has to wait 2 days until Thursday day 7 for next pickup to be transported to D1 for further transport to Unit 1 Production the same day. The order-to-delivery lead time for reaching Unit 1 Production is 3 days from Location A, 1 day from Terminal A, and up to 7 days from Location B.

8.1.2.3. Repacking and booking an air freight to Location F

When all orders that NN, Supply Chain Manager at Unit 1, wants to consolidate has been delivered to Unit 1 Production, which takes 5 days, the operators pack them together with the delivery note inside the pallet. The waybill is attached on the outside together with a paper informing the staff at D1 to send the pallet to Location A Terminal 10. The pallets are sent to D1 by elevator at 16:00. The pallets are transported by forklift from D1 to Location A Terminal 10, but since the day shift finishes at 16:00 the pallets are delivered the morning after.

When the pallets are delivered on next morning at Location A Terminal 10, a Supply Chain Manager at Location A terminal 10, books the air freight with Airline A, and a pick-up at the airport terminal. All pallets received are booked individually with no consolidation. According to the Supply Chain Manager the pallets are labeled with both shipment content and an address label. NN creates a virtual order in the system and receives a tracking number from Airline A which is sent to the Supply Chain Manager at Unit 1, who uses this number to keep track of the orders and updates their delivery dates to the facility at Location F in the Google document he shares with the facility. The Supply Chain Manager at Location A terminal 10, needs 1 day to make the booking and Airline A must have received the order before 14:00 to make a pick up the same day. As Location A Terminal 10 receives all pallets in the morning Airline A always pick up the orders the same day at 16:00.

8.1.2.4. The air freight to Location F and shipment to the facility

Airline A offers a door-to-door service to Company 1. To pick up the order at Location A Terminal 10 and send it to Location A, ship it to Location F, and finally arrange a transport to the facility. When studying transport statistics provided by the Supply Chain Manager at Unit 1, through tracking numbers; the lead time from Location A Terminal 10 until delivered to the facility has varied between 6 to 13 days. Going through the export statistics with Airline A, shows that the lead time from Location A to Location F is stable with 2-4 days. The order is picked up at Location A and sent to Location A on the same day, and thereafter it is often flown to Helsinki for consolidation before it is flown to Location F. After being delivered to Location F all orders are sent directly into Location F Customs warehouse and it is from this point where the lead times vary from 1-10 days. When the order is delivered to Location F airport; the air freight company sends all necessary paper works such as shipment content and invoice automatically to the facility's Broker. When the customs clearance is completed, Airline A receives a release notification and is able to book a final transport to the facility, taking 1 day.

8.1.2.5. Filling at the facility at Location F and shipping to Location A

At the facility at Location F, the basic products are filled with either a dry graphite mixture or a dry molybdenum disulfide mixture. These both lubricate and seal the products during operation, making them suitable for contaminated and extreme temperature applications. The Supply Chain Manager at Unit 1 gives the facility 2 weeks to perform the filling of the products when creating an order but usually they only need 7 days. The facility creates and label pallets with waybills and shipment contents, based on The Supply Chain Manager's documents. The status of the orders is updated in Google documents. According an Import Specialist at Airline A at Location A, Company 1 always buys a Airline B air freight service from Location F to Location A. Airline B air freight is the cheapest alternative where the order is consolidated with other orders for simultaneous flights. It has a quoted lead time of in best case 5-7 days from Location F to Company 1. When going through the import statistics provided by the Supply Chain Manager at Unit 1, the lead time from the facility to Terminal A varies between 6-18 days.

It is claimed that the only way to decrease the lead time is to order Regular flights, which have a promised lead time of 3-4 days. Shipping by regular flights 1 US$ more expensive per kg than shipping by Airline B which is a faster alternative. Airline B is used for the flights to the facility at Location F from Location A as well, but it is easier to get cheap and available get flight to Location F than the other way. When Terminal A receives the pallets, they often have problems identifying the receiver, since the shipment content document constantly have been removed. The only document attached to the pallet is the waybill, which does not contain any information about who is the final receiver or the P-order number that are used for tracking the final receiver. The staff at Terminal A solves the problem by contacting the Supply Chain Manager at Unit 1 upon receiving a pallet, to control if it belongs to Unit 1. The lead time is 1 day at Terminal A before they sent it with the daily transport next day to D1 or D3 to Unit 1 Production.

Table 26. The current product and information flow of Product 3 at Location F

	SUMMARY: The current product and information flow of Product 3 at Location F
	Total order-to-delivery lead times:
	- Basic products from Location F: 7-8 weeks
	- Basic products from Location B, Location A or Terminal A: 10-12 weeks
	Air freight lead times:
	From Location A terminal 10 to the facility: 6-13 days - Stable Airline B flight lead time: 2-4 days - Unstable lead time for customs clearance by the facility's Broker: 1-10 days
	From the facility to Terminal A: 6-18 days - Booking of Airline B flights with up to 4 consolidations before reaching Terminal A. - More difficult to get cheap and available Airline B flights from Location F to Location A.
	Identified problems:
1.	The products ordered from Location B are transported a detour to Company 2 and back before delivered to Unit 1 Production. Increases lead time with 4 days.
2.	Orders are consolidated for a week at Unit 1 Production before being sent to Location A Terminal 10. Increases lead time with 5 days
3.	Products ordered from Location B and Location A are packed when reaching Unit 1 Production. That is not the case for phosphated product from Terminal A. If Terminal A were able to pack the products, all products could have been delivered to Location A Terminal 10 directly since they label the pallets already today.
4.	The orders get stuck at Location F customs up to 10 days due to that Broker do not do the customs clearance in time after receiving the paper work from Airline A.
5.	The air freight lead time during the import process varies between 6-18 days due to ordering of Airline B flights that can be consolidated 4 times until delivered at Terminal A.
6.	The lead time at Terminal A is 1 day due to deliveries from Location A after the shipment of the daily transport. Pallets can get stuck on Terminal A due to that shipment notes are removed from the pallets.

8.1.2.6. Packing at Unit 1 Production and final delivery to customers

When creating the orders, Unit 1 Production is given 5 days to finish the packing and delivery of the orders at IDW Location A. Large orders of over 100 products are packed in the production line, orders of less than 100 products are packed manually and laser mark in the production line when the machine is available. Often the idle time in the production lines during double shield mounting is utilized for packing orders for Product 1 and 3. When the orders are packed the pallets are sent to Location A through the elevator at 16:00 in the end of the day. If not requesting "snabbinfackning" the total lead time through Location A is 5 days; 3 days for registering as RFP and 2 days for picking.

8.1.3. The upcoming Location A process flow of Product 3

Currently a process flow for Product 3, for both filling and packing, is under construction at Location A. The aim is to start filling those product designations with the expected highest sales volumes at Location A. Basic products for the upcoming filling process in Unit 1 production will be ordered from Terminal A and Location B. The products ordered from Location A are large dimensions that Unit 1 will not be dimensioned to produce. These large products will be transported to Location F just like today, along with some large 4*3 dimensioned phosphated designations available in stock Terminal A. The plan is, according to the Supply Chain Manager at Unit 1, to use the same the same product flows as today: To order products from Location B with 3 days lead time to the Hub, still taking the 4 days detour to Company 2 and back before being delivered at latest day 7 for starting filling and final assembly. The products from Terminal A are delivered day 2 to Unit 1 Production waiting for final assembly. The production line has 12 stations and a total lead time of 3 days due to long heating processes in the 2 ovens during the night. With potential increased volumes in the future, the lead time may be 4 days, due to two potential bottlenecks operations according to the Production Manager at Unit 1 Production. The dry graphite mixture and the dry molybdenum disulfide mixture, for filling the products in the new production lines, are made at Company 2. The mixtures are perishables with a life time of 1 week. Supply Chain order either a full or half a batch with an order-to-deliver lead time of 3 days.

Table 27. The upcoming product and information flow of Product 3 at Location A

SUMMARY: The upcoming product and information flow of Product 3 at Location A	
	Basic product ordering lead times:
	- Location B: 7 days (if available on stock) - IDWs: 2-6 weeks (if not available on stock)
	- From Terminal A: 1 day - Products from Location A will be sent to Location F.
	Production lead time:
	3 days.
	Identified problems:
1.	The products ordered from Location B are transported a detour to Company 2 and back before delivered to Unit 1 Production, increases the lead time with 4 days.
2.	The soaking and last heating operations could be potential bottlenecks due to its long cycle times and less capacity compared to previous operations, and that it is run during day time.
3.	No washing machine available close to production for designation 6007. Long lead times for being transported to RK-building.
4.	Some products demand up to 5 days extra lead time for modification before going through the production line of Product 3.

8.1.4. Are customers' needs fulfilled?

The only strategy for delivery to customers for Product 3 is make-to-order. The reason for this is that offering a product from almost any of Company 1's thousands of designations, and having too low sales volumes to enable identification of high runners, makes it hard to design an effective additional make-to stock delivery strategy. With lead times of 7-12 weeks, Product 3 does not fulfill any of the different customers lead time demands. Not even the non-urgent demand of 4 weeks is the current Product 3 product flow able to satisfy. Unit 1 has high expectations on Product 3 to grow and take market shares, which is difficult to achieve when not being able to satisfy new customers lead time demands. Short lead times are crucial for being able to reach new customer with new interest to enable for the product to grow. Today's lead times of 7-12 weeks exceed the investigated customer needs, inhibiting the product from growing. When only having a make-to-order strategy including at least 1 air freight between Location F and Location A, reaching the lead times demand of 1 week cannot happen. The only customer needs which can be potentially fulfilled with Product 3, is the non-urgent needs. When basic products are ordered from Location F, the shortest possible order-to-delivery lead time is 7 weeks. Suffering from long production lead times without being able to form a make-to-stock delivery strategy, investing in a production line at Location A was seen as the only alternative to reduce lead times.

8.2. Analysis

This section describes the analysis of the current system and which customer needs Unit 1 should focus on. The problems preventing Unit 1 from fulfilling the focus needs in the current process flows are identified.

8.2.1. Focus needs

Urgent needs with lead time demands of days up to 1 week will not be fulfilled with the future flow to fulfill with exclusively make-to-order production. The ordering lead times of products from Location B is 7-8 days: 2 days if booking sameday orders, 3-4 days lead time in Unit 1 Production, 1 day through Unit 1 if using sameday orders and "snabbinfackning", and 1 day for transport to customer. Unit 1 has the ambition for Product 3 to grow; reaching new customers, and existing customers with new interests are essential in order to succeed. These customers demand 1 week order-to-delivery time which the current Location F flow never can fulfill. The only flow that can get close to 1 week of order-to-delivery lead time is the future Location A flow. Since the future Location A flow has the best conditions for fulfilling both new customers' needs and non-urgent needs; the goal for the future should be to produce as many designations as possible in the Location A flow and on long term eliminate the Location F flow. Meanwhile the Location A flow is under implementation the Location F flow can be a complement for supplying non-urgent needs, especially for the Location F market. Especially for Product 3, a short lead time for the Business team is crucial. To enable for Product 3 to take market shares, it would be beneficial to supply the product to new customers to test, with short lead times.

8.2.2. Problems of fulfilling the focus needs in the current system

Since the new production line for filling of Product 3 in Unit 1 Production is still under start up, it is hard to make reliable process mapping of its operations. This thesis therefore focuses on the logistic flow; of ordering basic products from Location B, Location A and Terminal A, sent to either Unit 1 Production or to Location F for filling. When analyzing the current Product 3 product flow to Location F, several non-value adding activities are identified that contribute to the long total lead times. These are wastes such as unnecessary transports, waiting time, unnecessary material handlings and ambiguities. All these problems stop Unit 1 from fulfilling the needs of new interests and non-urgent needs in the current state flows.

8.2.2.1. Identified problems in the Location F process flow

Ordering of basic products from Location B, Location A and Terminal A

In order to get as short order-to-delivery lead times as possible, 1-3 basic products should be ordered from IDW Location F to as large extent as possible. If there are no products available at Location F, the products are ordered from Location B or Location A. 4*3 clearance are always ordered from Terminal A. The first waste identified is the extra transportation to Company 2 and back for products from Location B. As ordered products from Location B and Location A are already packed, the second waste is to have them repacked in Unit 1 Production. The problem is Terminal A that refuses to pick and pack orders, but only sends full pallets. The third waste identified is consolidation of orders in Unit 1 Production and have them packed together since this consolidation don't have any economic reasons but just adds lead time when waiting in 1 week instead of sending them directly one by one.

Customs clearance after air freight to Location F

The export process to Location F from Location A has a stable lead time of 2-4 days. What makes the lead time increase is the waste of waiting 1-10 days for the Broker to perform the customs clearance. The air flight company sends all work papers to the Broker directly when getting to Location F. The Broker then needs to perform the customs clearance so that Airline A can book a transport to the facility.

Variation in lead time for air freight to Location A

The air freight from Location F to Location A has a variation in lead time from 6-18 days. The reason for the variation is the problems of finding available flights and not having to consolidate to many times on the way to Location A.

Shipment from Location A to Unit 1 Production

Today the orders are transported to Terminal A from Location A leading to 1 extra day of lead time before being transported to D1/D3 and reaching Unit 1 Production. There are also wasteful activities performed at Terminal A due to the fact that the shipment content always is removed from the pallet. When not having that document the operators at Terminal A cannot find out where to send the pallet next, but requires time for investigations.

8.2.2.2. Identified problems in the Location A process flow

Long lead time for the Business team

The lead time for the Business team of 5-9 days when receiving requests of new interest is too long. This is especially problematic for Product 3 since it is a rather new product that Unit 1 has the ambition to grow, many cases has to go through the Business team when starting up the process at Location A.

The detour for basic product to the facility at Company 2

The transportation route to Company 2 for all basic products ordered from Location B adds 4 days extra lead time compared to if they had been sent directly from the Hub to D1. No value-adding work is conducted at Company 2.

Extra operations for some products

Due to problems of filling some products with the mixture used for filling Product 3, some products undergo 2 extra processes that adds 5 days extra lead time. This is too long if focusing on fulfilling customers' needs of new interests that demand 1 weeks lead time.

The daily transport from Terminal A

As Product 1, 2 and 3 share the same capacity in Unit 1 Production the more available time for the production the better if having a high workload. Since orders sent to Terminal A day 1 is often shipped day 2 already today an earlier daily transport day 2 than today's 13:00-14:00 would still give Terminal A 1 day to pick and load.

8.3. Proposals for an improved future system

This section describes the objectives for the future state flows and which improvements necessary for achieving them and fulfilling the focus customer needs.

8.3.1. Objectives for the future state flows

The focus for Unit 1 is to fulfill non-urgent needs and needs of new interests. None of these needs are today fulfilled with Product 3. When the Location A flow is fully implemented, the non-urgent needs will be fulfilled, provided a lead time of 10-16 days. The Location A flow will not fulfill needs of new interests with the current process. The focus for the Location F flow is to only fulfill non-urgent needs, and in a long term perspective all designations should be filled at Location A.

The improvement proposals aim to create 2 flows for filling at Location A; one fast process flow for customer orders of new interests, and one standard process flow for customer orders of non-urgent needs. The improvement proposals also aim to create a standard process flow for customer orders of non-urgent needs for filling in Location F to be used until the Location A flows are fully implemented.

Since the production lead time is 3 days in Unit 1 Production, a total order-to-delivery lead time of 5 days for the fast process flow at Location A will not be possible. The improvement proposals aim to create a flow with as short lead time as possible, even if it exceeds 1 week, by reducing identified waste in all processes.

8.3.2. Improvement proposals for the future state Location F process flow

Following improvement proposals will achieve a faster standard flow in Location F for fulfilling non-urgent needs. In total the proposals will reduce the total lead time for the Location F process flow from 7-12 weeks to 5-6 weeks by reducing identified wastes.

Persuade IDW Location F to keep a stock of basic products for Product 3

Unit 1 should persuade IDW Location F to build up a dedicated stock for their own needs. In order to minimize the air freights from Location A to the facility and have as many basic products as possible ordered from Location F, strive for building up a stock of basic products at Location F that often not are available in Location F but only on Location A or Location B. By doing this the products are sent in advance to Location F reducing the lead time for air freights.

Direct shipments into Location A Terminal 10

If no products are available at Location F, time is crucial. Therefore consolidation and repacking at Unit 1 Production should be eliminated and products should be delivered directly into Location A Terminal 10 from the Hub, Location A, and from Terminal A. Supply Chain should send all documents to NN at Terminal 10 for labeling the pallets and booking air freights as he does already today. In addition the transport to Company 2 and back for products from Location B should be eliminated, and Supply Chain should also get a direct contact with Location B established in order to reduce lead time with 1 day if placing sameday orders when receiving new customer orders.

This procedure requires that the pallets are packed when being delivered to Terminal 10, which the orders from both Location B and Location A are. Today all orders are booked individually so no consolidation should be done in order to reduce the lead time as much as possible for each order. All together these improvements reduce the lead time for products from:

- Location B with 8 days (9 days if direct contact and sameday order).
- Location A with 4 days.
- Terminal A with 4 days.

The lead time reduction is 4 days instead of 5 since the orders then will be delivered to Terminal 10 during the day which could be too late for being picked up by Airline A the same day. From Unit 1 Production the orders are delivered in the morning from D1 which gives Terminal 10 a full day to book air freights and pick up the same day.

Put pressure on the Broker

When air freight is used for transporting products to Location F the time is crucial. According to the flight statistics, the Broker delays the Location F customs. By putting pressure on the Broker to perform the customs clearance directly after receiving the paper work from the flight company, the lead time could be reduced to 2-4 days from Location A to Location F, 1 day for customs clearance and 1 day for transporting to the facility, the delivery time can be stabilized on 6 days.

Order regular flights from the facility to Location A

Today Airline B flights are used both ways, but according to Airline A it is more difficult to find available consolidation flights to Location A than to Location F. The only way to get a shorter deliver lead time than 18 days is to order regular flights. Regular flights charge 1 US $ more per kg goods than Airline B flights, but has a stable lead time of 3-4 days.

Redirect the transport from Location A to D1

After the order has landed on Location A it is transported to Terminal A to be delivered. From here it is delivered first next day to D1/D3. In order to save 1 days lead time, have the orders delivered directly to D1 instead. Then the orders reach Unit 1 Production on the same day.

Add “Unit 1” in the address box in the shipment content

In order to handle the problem with removed shipment content documents from the pallets; “Unit 1” should be added in the address box on the waybill attached to the pallet.

Table 28. Improvements for reducing the lead times in the future Location F flow

SUMMARY: Improvements for reducing the lead times in the future Location F flow	
- New total order-to-delivery lead time for basic products ordered from Location B: About 6 weeks, compared to today's 10-12 weeks **- New total order-to-delivery lead time for basic products ordered from Location A and Terminal A:** About 5 weeks, compared to today's 7-8 weeks	
1.	Eliminate the transport to Company 2 and back from the Hub for basic product ordered from Location B. Have them delivered directly into Location A Terminal 10 from the Hub. Reduces lead time with 4 days for basic products ordered from Location B. Enables elimination of repacking.
2.	- Basic products ordered from Location A should be delivered inhouse directly to Terminal 10 instead of to Unit 1 Production. Enables elimination or repacking. - Terminal A should pick and pack orders of basic products for the Location F flow and deliver them directly into Location A Terminal 10 instead of to Unit 1 Production. Enables elimination of repacking in Unit 1 Production.
3.	Eliminate the repacking and consolidating process at Unit 1 Production. Supply Chain should send all documents to Location A Terminal 10 for booking air freights and labeling the pallets as he already do today. Reduces lead time with 4 days.
4.	Stabilize the air freight lead time from Location A to the facility at Location F to 6 days. Put pressure on the Broker to do the customs clearance directly as he receive the paper work by the air flight company. 4 days from Location A to Location F, 1 day in Location F Customs for doing customs clearance, 1 days transport to the facility.
5.	Regular flights should be used for transporting orders from the facility to Location A in order to stabilize the air freight lead time to 3-4 days. Has a higher cost of 1 US $ per kg but has a shorter and more stable shipment lead time.
6.	Redirect the transport from Location A to be delivered to D1 instead of Terminal A. Saves 1 days lead time. By writing Unit 1 in the address box in the waybill, staff at D1 knows where to send the pallet even if the shipment content document is removed.
7.	Persuade Location F to build a stock of basic products for Product 3 which usually has low availability. Eliminates the lead time for the air freight from Location A to Location F.

8.3.3. Improvement proposals for the future state Location A process flow

Following improvement proposals will achieve a standard flow and a fast flow at Location A for fulfilling non-urgent needs and needs of new interests. In total the proposals will reduce the total lead time for the standard flow from 10-16 days to 10-12 days, and create a fast flow with a lead time of 6 days.

Reduce the lead time for the Business team to 1 day

The Business team is mostly needed when receiving new interests and new interest demand 1 week's order-to-delivery lead time. If Unit 1 should be able to deliver a test product in 1 week only 1 day for the Business team can be accepted and this day is taken from Unit 1 Productions 2 days. One way to decrease the lead time in the business team is to instead of having a serial process having a parallel process where each of the 4 persons involved investigate their own parts simultaneously. Then the theoretical lead time is 1 day. Another way is to move investigation if certain aspects, such as packing, to be perform and solve those problems after hand.

Non-value adding detour transports of basic products from Location B

The detour to Company 2 and back for product ordered from Location B must be eliminated. Location B is the largest warehouse for basic product for the future flow at Location A and lead times are crucial when having order from new customers, then these products must be transported as short distances as possible. Since the basic products are to be filled in Unit 1 Production, the shortest lead time is achieved if the orders from Location B are delivered from the Hub directly to D1 for transport to Unit 1 through the elevator the same day.

Sending the daily transport from Terminal A earlier to D1/D3

The daily transport from Terminal A, arriving at 13:00-14:00 to D1 and D3, gives Unit 1 Production only 2-3 hours to start the orders the same day. Since the flow mapping already count with 1 days lead time from Terminal A, the lead times are shorter if the daily transport is shipped in the early morning to D1/D3 instead of after lunch. By changing the daily shipment time for the daily transport to early morning Unit 1 Production is given 4-5 hours more time to be able to start an order the same day when receiving new customer orders. Terminal A will still have 1 whole day for picking an order and place it in the shipment area.

Standard process for new customers

As the lead time spent at Unit 1 Production is 3-4 days, basic product should be delivered with as short lead time as possible and sent through Location A to customers with as short lead time as possible. To achieve shortest possible lead time from Location B of 1 day, a direct contact must be established for Supply Chain that enables placing sameday orders. From Terminal A is the ordering lead time 1 day but no basic products will be ordered from Location A. By changing the daily shipment from Terminal A to Unit 1 Production they get 4-5 hours more time to start the order the same day. When sending the finished orders through Location A to customers, “snabbinfackning” must be used with a combination of placed sameday order from the Sales Unit or the Distributor in order to ensure fast registration as RFP and fast picking and shipping after being registered as RFP. From Location B this standard process would result in a total lead time of 5-6 days before being shipped to customer, depending on how early Unit 1 Production can start the order. If ordering basic products from Terminal A the total lead time is 1 day shorter.

Standard process for non-urgent needs

As non-urgent needs allow for longer lead times, normal orders of 3 days lead time is short enough when ordering basic products from Location B. The same goes for when ordering basic products from Location A, offering 3 days lead time for picking and shipping stock items. As these are non-urgent needs Unit 1 Production can be given 1 day to start the order just like for Product 2. The accepted lead time through Location A for finished orders is 3 days registering as RFP and 2 days picking and shipping. From Location B this standard process would result in a total lead time of 10-11 days depending on how early Unit 1 Production can start the order, before being shipped to customer.

8.3.3. Expected results

If not regarding the possibilities of building up a stock of basic products at Location F in advance, these improvements will reduce the total lead time for the Location F flow of Product 3. A basic product ordered from Location B, Location A and Terminal A will be shipped from Location A to customer on day 28-29 which results in an order-to-delivery lead time of about 6 weeks compared with today’s 10-12. A product from IDW Location F will be shipped from Location A to customer on day 24 which results in an order-to-deliver lead time of about 5 weeks compared to 7-8 weeks today. In the long term perspective the Location A flow has the best conditions for achieving low lead times. Therefore the Location F flow could be used during the start up at Location A and thereafter only be used for complex cases due to the flexibility and experience at the Location F facility.

The improvements for the Location A flow will reduce the lead time for the standard flow from 10-16 days to 10-12 days and improve the conditions for having a fast flow. Even though the conditions are improved the total order-to-delivery lead time of 6 days exceeds the lead times demanded by the customers with 1 day.

Table 29. Improvements for reducing the lead times in the future Location A flow

SUMMARY: Improvements for reducing the lead times in the future Location A flow	
Total order-to-shipment lead time for new interests and customers orders: 5-6 days from Location B depending on how early Unit 1 Production can start the order.	
1.	When receiving a customer order for a new interest; Company 1 Sales Unit's Customer Service and the Distributors must register the order as a sameday order in the system. This in order to ensure picking and shipping within 24 hours from when the order has been registered RFP.
2.	When Unit 1 Production sends the finished order to Location A the pallet must be labeled on top with a paper signed "snabbinfackning". This is on order to ensure that the pallets is registered RFP directly after goods receipt at Location A.
3.	The shipment time for the daily transport from Terminal A to D1/D3 must be changed from 13:00-14:00 to as early as possible in the morning. This ensure that all phosphated products and shields ordered day 1 is delivered to Unit 1 Production in the morning day 2, giving them a whole day to start the order the same day.
4.	Establish a direct contact from Supply Chain to Location B to allow for placing sameday orders for basic products without going through the Sales Unit. Reduces lead time with 1 day.
5.	Eliminate the transport to Company 2 and back from the Hub for basic product ordered from Location B. Have them delivered directly to D1 from the Hub. Reduces lead time with 4 days for basic products ordered from Location B.
Total order-to-shipment lead time for non-urgent orders: 10-11 days from Location B depending on how early Unit 1 Production can start the order.	
6.	Placing normal orders to Location B of 3 days is enough. Still the detour to Company 2 and back should be eliminated; orders should be delivered to D1 directly from the Hub.
7.	Using normal procedures through Location A for registering as RFP in 3 days and picking/shipping in 2 days are enough.
8.	Just like for PRODUCT 2 Unit 1 Production should have 1 day to start the orders which enables more flexible production planning.
9.	The finished Product 1 should be delivered from Company 2 directly to Location A Terminal 9, plan 100. The mixture made at Company 2 should be delivered with the same transport to D1.
10.	Increase capacity in the Location A flow to be able to fill as many designations as possible at Location A to eliminate the longer lead times of the Location F flow.

9. Discussion

The improvement proposals of this master thesis aim to primarily reduce the order-to-delivery lead times for the Unit 1 product flows of Product 1, 2 and 3. The lead time reduction has the purpose of adapting the lead times of the flows to what customers find acceptable, in order to attract new customers and increase the sales.

After investigating both the categories of customer needs and how each product flow is designed to fulfill these needs, it was found that not all flows are successful or have the potential to fulfill all needs at the time of the study, or in the future.

The urgent needs of 12 h-2 days can only be fulfilled by having finished goods products available for delivery, which require a make-to-stock strategy.

New interests and new customers' needs of 1 week require, if not a make-to-stock strategy, access to basic products and components for a prioritized production process for a make-to-order strategy.

Non-urgent needs of up to 4 weeks allow for a make-to-order strategy with longer lead times. It still has to be combined with the ability of delivering small order volumes in 1 week, because few new customer order larger volumes of products without first having ordered test products for evaluation.

The easiest way to fulfill all 3 needs would be to implement a pure make-to-stock strategy for all 3 products. Such a solution is not possible due to certain conditions. Since Unit 1 offer both Product 1 and 3 from any of Company 1's thousands of designations, a make-to-stock strategy would be unreasonable for these 2 products. For product 1 however, an additional make-to-stock strategy for 8 high running designations, accounting for almost half of total sales volume, is established. Since Product 3 is rather new on the market and still have low sales volumes, no high runner have been identified. Product 2 offers the best conditions for having a make-to-stock strategy, by offering the customers a limited range of 200 final designations. Out of these 49+25 designations are currently stock items. Due to the pressure within Company 1 on lowering inventories and tied-up capital, make-to-stock strategies for Unit 1's all 3 products is at the time of the study not possible.

As no increase of stock items is possible for any of the 3 products, the current make-to-order strategies have to be improved to fulfill the lead time demands. When having a make-to-order strategy, fulfilling lead times of 2 days to meet the urgent needs is not possible. Because of this, the urgent customer need is not considered. Instead the focus was to create product flows which fulfill both new interests and non-urgent needs. The improvement proposals are aimed at creating two flows for each product; one fast flow with total lead time of 1 week for new interests, and one standard flow with lead times less than 4 weeks for non-urgent needs.

Achieving 2 solutions for the flows of Product 1 resulted in increased lead times with 4 days for today's 8 stock items when just having a finished goods stock at Company 2. This lead time increase was necessary in order to free tied-up capital for increasing availability of basic products by increasing the basic product stock at Company 2, enabling for more production in machine. Increased lead time for the stock items, result in decreased lead time for all non-stock items. This gives a total lead time of less than 4 weeks when increasing the capacity in the system's bottleneck. In addition, the largest customer of Product 1, for whom the stock items are identified, accepts lead times of 4 weeks. According to this, the increased lead time from 1 week to 2 weeks still fulfill the demand. The fast flow of Product 1 will be able to deliver products in 1 week but it will be more expensive when not using Company 1's transport system for final delivery to customers. This should be seen as an investment for increasing sales and enabling increased sales to new customers.

The current flow for Product 3 at Location F does not fulfill any customer needs. Even after improving the flow and its current conditions, like ordering basic products from Location F and booking regular flights to Location A, the total lead time will still exceed 4 weeks. The only way to increase sales for Product 3 is to grow the production capacity in the future Location A flow to handle as many designations as possible. The future flow will fulfill non-urgent needs by its standard flow but achieving a fast flow for new customers is more challenging. The production lead time is 3-4 days in Unit 1 Production, and ordering of basic products from Location B or Terminal A takes at least 1 day, 1 week lead time could be reached with a make-to-stock strategy.

With its 49+25 stock items Product 2 already today fulfills new interest needs for these designations. With an order-to-delivery lead time of 2-3 weeks as standard it fulfills all non-urgent need by far. There are two ways of fulfilling the needs of new customers for all designations; either to have a pure make-to-stock strategy for all 200 designations, or to have the stock of all needed components at hand at Company 1 with 1 day lead time in a make-to-order strategy. In this master thesis project the last option was chosen because it is cheaper to have components on stock ready for a final assembly order than having finished goods on stock. By having the stock of graphite at Company 1 it enables lower stock levels of finished goods which freed tied-up capital can be used for financing the graphite stock.

In this master thesis project not only lead time related improvement proposals were developed. Also capacity related improvement related proposals are presented, because the production of Product 1, 2 and 3 share the same staff and packing line capacity in Unit 1 Production. By increasing capacity for the operators and packing line and moving the packing operation for Product 1 to Company 2 the increased capacity will also affect the production of Product 3. As Unit 1 has the ambition of increasing sales for Product 3, the freed capacity required will be very useful in the future. The costs involved in moving the packing to Company 2, requires that the increased capacity is used for value adding work for increased sales of Product 2 or 3.

10. Conclusions

The purpose of the thesis was to improve the product flows for Product 1, 2 and 3. The intention with the purpose was enable increased sales for Unit 1, by reducing the lead times for the make to order production in order to better meet customer needs. The purpose is obtained by eliminating waste and increasing the capacity in the three product flows.

The problems perceived by Unit 1, is that potential customers are difficult to attract due to long lead times for the make to order production. Unit 1 supplies both OEM and AMC customers. The customer categories have differing demand in terms of delivery reliability and short lead times due to their differing possibilities to forecast their own needs. The product range of Unit 1 products is wide, making the customer demand is therefore difficult to foresee. Exclusive make to stock production is therefore not a realistic option. The studies conducted indicated that the accepted lead times generally are lower than the quoted lead times in the current product flows.

The investigations and analysis of the current state showed that there is waste in the production flows in terms of excessive transportation and material handling activities. That is particularly the case for the Product 3 production where the filling processes are outsourced to a partner at Location F. Pre-processes needed for modification and preparation of the basic products prior to production are time-consuming and can to a large extent be avoided by ordering basic products which during manufacture are adapted to the Unit 1 production.

The objective to meet the customers' non urgent needs with non-stock items, are achieved for the production of Product 1 and 2. The needs will be fulfilled with the non-stock items of Product 3 produced in the Location A production flow, which at the time of the study is under construction. The needs are not fulfilled with Product 3 produced in Location F. The needs for new interests are for Product 2 only met with two of the non-stock items. For Product 1, the needs for new interests are met with all non-stock items, provided that a fast flow is implemented. For Product 3, the needs for new interests are barely met with non-stock items produced at Location A. The urgent needs cannot be met with the non-stock items for any of the products. For stock items however, all three needs are met for Product 1 and 2.

The second objective is measured after the improvements potentials to increase the capacity of the product flows by removing the sources of waste in the product flow. Below is an extract of improvement suggestions presented:

For Product 1, capacity increase is obtained by ordering basic products without seals and grease, saving 13-15 hours per batch. By phasing out the stock of Product 1 at Location A, tied-up capital is freed. The freed tied-up capital can be used for an increased number of basic product stock items, providing for filling more designations in the filling machine, which is four times faster and the dressing twelve times faster than the manual filling processes.
For Product 2, the capacity is increased by ordering more basic product without cage from the factories for item3 and item4. By doing this the cage removal process can be eliminated, saving 2.05 hours for 1 operator/workday. By having these two designations manufactured without cage and with 1 shield mounted on, the bundling process can be eliminated adding additional savings accounting for 0.25 hours for 1 operator/workday.

By ordering and phosphating basic products with 1 shield mounted, the double shield mounting process can be eliminated for item3 and item4. This improvement would reduce the lead times through the production line with 45 % and increases its capacity with 81 %.

For the Location F Product 3 product flow, the capacity is increased by eliminating the repacking and consolidating process at Unit 1 Production. The lead time is reduced with 4 days if Unit 1 Supply Chain sends all documents to the logistician NN at Location A Terminal 10 for booking air freights and labeling the pallets.

11. Recommendations

In this chapter all improvements proposals are summarized into one table for each product flow. In the tables the improvements proposals are divided into 4 categories; dependent or independent, and simple or demanding. The numbers in the left column show which improvement proposals that are dependent and in which sequence they should be implemented. The improvement proposals without numbers are independent and don't need to be implemented in a certain sequence. Simple improvements that can be implemented immediately without any larger effort have white backgrounds and demanding improvements have grey background in the tables.

Table 30. Implementation plan for Product 1 future state flow

Implementation plan for Product 1 future state flow		
	Simple improvements	**Demanding improvements**
1.	Increase capacity in vacuum chamber *Larger batch sizes provide for higher efficiency in the constraining dressing process.*	
2.		Develop shields milled on both sides for the pressing process. One shield can be used for two products. *Reduces the pressing process time. More products fit in each fixture and can be baked simultaneously.*
3.	Standardize the manual filling operations at Company 2 and establish a working schedule. *Reduces waste of waiting times.*	
4.	Let the constraining process, which is the dressing, govern the production. Batch sizes of 75-83, depending on 1 or two production runs, are adapted to the capacity of the dressing process. *Optimizes the dressing capacity and thereby reduces the lead times for non-stock items.*	
5.		Outsource the packing and laser marking processes to Company 2. Requires investments of laser marker, was printer and establishing of access to Company 1 order handling systems. *Eliminates material handling activities at Unit 1 Production. Reduces production lead times. Provides for fast deliveries Company 2-final customer.*
6.	Reroute transports of Product 1 products from Company 2 directly to Location A, terminal 9 floor 100. *Eliminates material handling at D1 and Unit 1 Production.*	
7.		Remove the stock of Product 1 designations at Location A to only have stocks at Company 2. *Frees tied-up capital which can be used to increase the number of stock item designations.*
8.	Increase the number of stock item designations at Company 2, preferably with designations with long lead times for production or supply of basic products. *Decreases the lead times for delivery of basic products. Higher volumes of basic products in stock provides for filling more designations by machine.*	
9.	Increase the number of designations filled by machine. *Frees capacity in the dressing process, decreases the lead times for the manually filled designations.*	
10.	Established an improved standard flow: Unit 1 Supply Chain place normal orders to Location B/IDWs. Delivery to Company 2 by truck and Company 1 internal transport. The filling, laser marking and packing processes are completed within 5 days. Delivery with Company 1 internal transport to Location A, terminal 9, floor 100. Transport to final customer by FTC. *Decreases the lead time from customer order to delivery from 4-6 weeks to 3-4 weeks.*	

11.	Establish a fast flow: Customer Service place same day orders to Location B/IDWs. Transport to Company 2 by FTC. Forcing products through the filling, laser marking and packing processes in 1 day. Urgent transport directly to customer by courier. Lead times of 1-2 weeks from customer order to delivery.
	Introduce direct contact between Location B-Unit 1 Supply Chain ordering systems. *Eliminates delays for order placement and reduces the lead time by one day for basic product orders*.
	Establish access for Unit 1 Supply Chain to order optional minimum volume from Location B/IDWs. *Eliminates excess orders of basic products*
	Order basic products packed in cassettes. *Reduces time for unpacking at Company 2*
	Reroute transports of basic products from IDWs directly to Company 2 *Reduces lead time by 1 day, eliminates handling of basic products at Unit 1 Production.*
	Systematically go through the changeover process for the filling machine to reduce changeover times. *Provides for filling non-stock items with high yearly demand by machine*

Table 31. Implementation plan for Product 2 future state flow

<table>
<tr><th colspan="3">Implementation plan for Product 2 future state flow</th></tr>
<tr><th></th><th>Simple improvements</th><th>Demanding improvements</th></tr>
<tr><td>1.</td><td colspan="2">Persuade the IDWs to allow ordering of basic products in lower quantities eqv to 1 batch size.
Reduces inventory levels and space needed at Terminal A. Frees up tied-up capital. Enables for Unit 1 to order more basic products without cage.</td></tr>
<tr><td>2.</td><td colspan="2">Ensure that Company 3 phosphates basic products with 1 shield mounted on.
Enables for Unit 1 to order basic products without cage with 1 shield mounted on.</td></tr>
<tr><td>3.</td><td colspan="2">Use the freed tied-up capital to order basic products from IDWs in 2 categories for each designation:
- With cage (suitable for item1, item2 and Product 3)
- Without cage and with 1 shield mounted on (suitable for item3 and item4)
Eliminates “bundling”, “cage removal” and “double shield mounting” at Unit 1 Production, and material handlings at D1 and Terminal A. Saves 2,3 hours for 1 operator/workday in Unit 1 Production and reduces lead time in the production lines with 46 %.</td></tr>
<tr><td>4.</td><td colspan="2">Ensure that Distributors and Customer Service always places sameday orders when having new interests.
Orders are shipped in the morning day 4 from Location A. Gives 2 days transport to customers.</td></tr>
<tr><td>5.</td><td colspan="2">Unit 1 Production should always use “snabbinfackning” when sending finished orders of new interest to Location A on day 3.
Ensures that the orders are registered as RFP and picked the same day 3.</td></tr>
<tr><td>6.</td><td colspan="2">The finished goods stock of graphite components should be located at Company 1, preferably in D3 Basement, in order to reduce the delivery lead time from 3-5 days to 1 day.
Enables for Unit 1 Production to finish final assembly and send orders to Location A on day 3.</td></tr>
<tr><td>7.</td><td colspan="2">The lead time for the cage removal process of 3 days must be reduced to 1 day.
- Either by using an oven to reduce the drying lead time after washing.
- Or replacing the washing/drying processes with blowing the products clean by using high pressure air.
Enables for Unit 1 Production to finish final assembly and send orders to Location A on day 3.</td></tr>
<tr><td>8.</td><td colspan="2">Change the shipment time to early morning for the daily transport from Terminal A to D1/D3.
Orders sent to Terminal A day 1 are delivered in the early morning day 2: gives Unit 1 Production two whole days for finishing small customer orders of new interests and send to Location A on day 3.</td></tr>
<tr><td></td><td colspan="2">Persuade the Distributors to not consolidate all orders received during the day for simultaneous ordering at 18:00, but to place orders directly in the system when receiving them.
Eliminates 1 days lead time.</td></tr>
<tr><td></td><td colspan="2">Ensure that Company 3 pack all products and shields directly into pallets after phosphating.
Eliminates repacking at Unit 1 Production and material handlings at D1 and Terminal A. Saves 0,34 hours for 1 operator/workday in Unit 1 Production.</td></tr>
<tr><td></td><td colspan="2">Order basic products to be packed in “kassetter” in pallets from the IDWs
Ease the phosphating process for Company 3 when being able to pour products into the tumbler.</td></tr>
<tr><td></td><td colspan="2">Reduce the number of shipments from the graphite supplier; from 2 to 1 transport per week.
Reduces shipment costs, only 1 transport per week for refilling the stock.</td></tr>
<tr><td></td><td colspan="2">Develop a signal system for the elevator in D3 for sending and receiving goods.
Eliminates problems connected to transportations and elevator availability.</td></tr>
<tr><td></td><td colspan="2">Develop a fixture for reducing the cycle time for graphite assembly of VA208 and VA228.
If reducing the cycle time from 20 sec to 12 sec, only 2 operators are needed instead of 3.</td></tr>
</table>

	Have a clear main addressee in the e-mails to Terminal A and Company 3 when ordering phosphating. *Eliminates uncertainties of who is responsible in urgent situation if being specific to both.*
	Implement standardized work methods in Unit 1 Production for all assembly operations. *Ensures that all operators are applying the current best way of working to cut lead times.*
	Redesign the laser marking machine in production line 2 to be able to laser mark phosphated products. *Eliminate the material handlings when lifting large products to Line 1 for laser marking and back.*
	Change places on the laser marking machines in Line1 and Line2 to match the shield mounting machines. *Eliminates the material handlings when lifting products between the production lines.*
	Lower the finished goods stock levels at IDW Ggb, when having shorter lead times for refilling the stock. *Reduces inventory levels and frees up tied-up capital when being able to refill the stock in 2 days.*
	Unit 1 should put pressure on Location A to reduce the lead time for registering goods as RFP. *3 days for registering non-stock items as RFP and 2 days for picking and shipping, results in 5 days lead time to just get through Location A for a standard make-to-order product flow.*

Table 32. Implementation plan for Product 3 – Location A future state flow

Implementation plan for Product 3 - Location A future state flow	
	Simple improvements / **Demanding improvements**
	Persuade the Distributors to not consolidate all orders received during the day for simultaneous ordering at 18:00, but to place orders directly in the system when receiving them. *Eliminates 1 days lead time.*
	When receiving a customer order for a new interest; Company 1 Sales Unit's Customer Service and the Distributors must register the order as a sameday order in the system. *This in order to ensure picking and shipping within 24 hours from registered as RFP.*
	Unit 1 Production should always use "snabbinfackning" when sending finished orders of new interest to Location A. *Ensures that the orders are registered as RFP the same day, to enable shipment within 24 hours.*
	Establish a direct contact for Supply Chain towards Location B without night batch in order to place sameday orders for basic products when receiving order for new interests. *Reduces lead time with 1 day.*
	Eliminate the detour transport to Product 1 and back from the Hub for basic product ordered from Location B. Have them delivered directly to D1 from the Hub. *Reduces lead time with 4 days for basic products ordered from Location B.*
	Change the shipment time to early morning for the daily transport from Terminal A to D1/D3. *Orders sent to Terminal A day 1 are delivered in the early morning day 2. This gives Unit 1 Production 4-5 more hours for starting orders of new interests the same day.*
	Develop a signal system for the elevator in D3 for sending and receiving goods. *Eliminates problems connected to transportations and elevator availability.*
	Unit 1 should put pressure on Location A to reduce the time needed for registering incoming goods as RFP. *3 days for registering non-stock items as RFP and 2 days for picking and shipping, results in 5 days lead time to just get through Location A for a standard make-to-order product flow.*
	Increase the number of product designations that can be filled in Unit 1 production. *Eliminates the air freights back and forth to Location F and their long lead times.*

Table 33. Implementation plan for Product 3 – Location F future state flow

Implementation plan for Product 3 - Location F future state flow		
	Simple improvements	**Demanding improvements**
1.	Eliminate the detour transport to Product 1 and back from the Hub for basic product ordered from Location B. Have them delivered directly into Location A Terminal 10 from the Hub. *Reduces lead time with 4 days for basic products ordered from Location B. Enables elimination of repacking.*	
2.	Redirect the basic products ordered from Location A to be transported directly inhouse to Terminal 10 instead of to Unit 1 Production. *Enables elimination of 4 days lead time.*	
3.	Persuade Terminal A to pick and pack only the basic products which are to be transported to Location F, and sending them directly to Location A Terminal 10. *Enables elimination of 4 days lead time.*	
4.	Eliminate the repacking and consolidating process at Unit 1 Production. Supply Chain should send all documents to the Supply Chain Manager at Location A Terminal 10 for booking air freights and labeling the pallets as he already do today. *Reduces lead time with 5 days in Unit 1 Production but increases lead time with 1 day in Terminal 10.*	
	Demand the broker to perform the customs clearance directly when he receives the documents from the air freight company, so that Airline A can arrange shipments to the supplier. *Reduces lead time with up to 10 days in Location F Customs. Stabilizes the lead time from Location A to the supplier to 4-6 days.*	
	Use regular flights for transporting from the supplier to Location A in order to stabilize the air freight lead time to 3-4 days. Consolidation flights from Location F to Location A have large variations in lead times. *Has a higher cost of 1 US $ per kg but has a shorter and more stable shipment lead time.*	
	Redirect the transport from Location A to be delivered to D1 instead of Terminal A. By writing Unit 1 and the P-order number in the address box in the waybill, staff at D1 always knows where to send the pallet even if the shipment content document is removed. *Reduces 1 days lead time end eliminates ambiguities of where to send the pallets.*	
	Persuade IDW Location F to allow Unit 1 to build a stock of basic products for Product 3 which usually have low availability in Location F. *Eliminates the lead time for the air freight from Location A to the supplier.*	
	Develop a signal system for the elevator in D3 for sending and receiving goods. *Eliminates problems connected to transportations and elevator availability.*	
	Unit 1 should put pressure on Location A to reduce the lead time for registering goods as RFP. *3 days for registering non-stock items as RFP and 2 days for picking and shipping results in 5 days lead time to just get through Location A for a standard make-to-order product flow.*	

12. References

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12.2. Interviews

Customers' needs

1. NN, Business Engineer at Global Metal Segment, Company 1.
2. NN, Account Manager at Sales Unit, Company 1.
3. NN, Customer Service at Sales Unit, Company 1.
4. NN, District Manager at Distributors.
5. NN, Business Engineer at Global Food and Beverage Segment, Company 1.
6. NN, Business Development at Unit 1, Company 1.
7. NN, Manager of Business and Product Development at Unit 1, Company 1.

Company 1 Warehouses and transportations

8. NN, Logistician at Company 1.
9. NN, Transport Manager at Company 1
10. NN, Manager at Terminal A, Company 1.
11. Staff at Terminal A, Company 1.
12. Staff at Terminal D1, Company 1.
13. NN, Supply Chain Manager at Location A Terminal 10, Company 1.
14. NN, Manager at Company 1 Logistics Services Location B.
15. NN, Customer Service at Company 1 Logistics Services Location B.
16. NN, Truck driver.

The Product 1 product flow

17. NN, Supply Chain Manager at Unit 1, Company 1.
18. NN, Supply Chain Manager at Unit 1, Company 1.
19. NN, Manager at facility at Company 2.
20. Operators at facility at Company 2.
21. NN, Manager at Unit 1 Production, Company 1.
22. Operators at Unit 1 Production, Company 1.

The Product 2 product flow

23. NN, Supply Chain Manager at Unit 1, Company 1.
24. NN, Supply Chain Manager at Unit 1, Company 1.
25. NN, Production Manager at Company 3.
26. NN and NN, Phosphating Technician and Operator, Company 3.
27. NN, Manager at graphite Supplier.
28. NN, Manager at Unit 1 Production, Company 1.
29. Operators at Unit 1 Production, Company 1.
30. NN, Development Engineer at Unit 1, Company 1.
31. NN, Development Engineer at Unit 1, Company 1.

The Product 3 product flow

32. NN, Supply Chain Manager at Unit 1, Company 1.
33. NN, Export Specialist at Airline A, Location A.
34. NN, Import Specialist at Airline A, Location A.
35. NN, Manager at Unit 1 Production, Company 1.
36. Operators at Unit 1 Production, Company 1.
37. NN, Supply Chain Manager at, Location A.