IMPROVING PRODUCT DELIVERY PROCESS QUALITY

Lappeenranta–Lahti University of Technology LUT

Master's degree program in Industrial Engineering and Management

2023

Hanno Brander

Examiner: Professor Petri Niemi

Supervisor: Kari Niemi

ABSTRACT

Lappeenranta–Lahti University of Technology LUT

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Hanno Brander

Improving product delivery process quality

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74 pages, 14 figures and 2 tables

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Keywords: Mistake proof, System-driven, Delivery process, Quality management

The topic of this thesis is improving the quality of the outgoing products delivery process in a company specializing in measurement solutions. The goal of the work is to investigate which factors affect the quality of the delivery process and to find the reasons for incorrect shipments sent to customers. In the final phase of the work, possible improvement measures and their effect are also investigated. The theory is created through literature research on the structure of the delivery process, metrics, and quality management. The case study is carried out with data analysis, interviews, process monitoring and piloting.

Based on the findings in this work, balancing between better quality and efficiency of the process can be very difficult. Especially if the manufactured products differ from each other and therefore the implementation of standardized procedures is not always possible or viable. Due to the complexity and customizability of the products it is not possible to use external non-integrated systems. If you want the delivery process to be mistake proof, its operation must be based on system-driven verification methods, the use of which works smoothly as part of the process.

As a result of the research and the pilot, we are going to modify the packing points of the freight packing area to make it possible to read barcodes when packing products. This makes it possible to immediately change the packaging process of smaller products packed in product boxes to a system-driven one. At the same time, structural requirements are recommended for new products. Goods outside the main product can be easily identified either from their own order line or all goods can be placed in a marked product box to avoid problems related to identification in the future.

TIIVISTELMÄ

Lappeenrannan–Lahden teknillinen yliopisto LUT

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Tuotantotalouden koulutusohjelma

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Tuotteiden toimitusprosessin laadun parantaminen

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Tämän diplomityön aiheena on lähtevän tavaran toimitusprosessin laadun parantaminen mittausratkaisuihin erikoistuneessa yrityksessä. Työn tavoitteena on tutkia, mitkä tekijät vaikuttavat toimitusprosessin laatuun ja löytää syyt asiakkaille lähetetyille virheellisille lähetyksille. Työn loppuvaiheessa tutkitaan myös mahdollisia parannustoimenpiteitä ja niiden vaikutusta. Teoria luodaan kirjallisuustutkimuksella toimitusprosessin rakenteesta, mittareista ja laadunhallinnasta. Tapaustutkimus toteutetaan data-analyysillä, haastatteluilla, prosessiseurannalla ja pilotoinnilla.

Työssä tehtyjen havaintojen perusteella tasapainottelu prosessin paremman laadun ja tehokkuuden välillä voi olla hyvinkin vaikeaa. Erityisesti, jos valmistettavat tuotteet eroavat toisistaan ja siksi standardoitujen toimintatapojen implementointi ei aina ole mahdollista tai kannattavaa. Tuotteiden kompleksisuuden sekä muokattavuuden johdosta ulkoisten ei integroitujen järjestelmien hyödyntäminen ei ole mahdollista. Mikäli toimitusprosessista halutaan virheenkestävä, tulee sen toiminnan perustua järjestelmäohjautuviin varmistusmenetelmiin, joiden käyttö toimii sujuvasti osana prosessia.

Tutkimuksen sekä pilotin tuloksena lähdetään rahtipakkaamon pakkauspisteitä muokkaamaan sellaisiksi, että ne mahdollistavat viivakoodien lukemisen tuotteiden pakkauksen yhteydessä. Tämä mahdollistaa heti pienempien tuotelaatikoihin pakattujen tuotteiden pakkausprosessin muuttamisen järjestelmäohjautuvaksi. Samalla uusille tuotteille suositellaan rakenteellisia vaatimuksia, että päätuotteen ulkopuoliset tavarat voidaan helposti tunnistaa joko omalta tilausriviltään tai kaikki tavarat voidaan sijoittaa merkittyyn tuotelaatikkoon, jotta tunnistamiseen liittyviltä ongelmilta vältytään tulevaisuudessa.

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Helsinki, 15 June 2023

Hanno Brander

ABBREVIATIONS

B2B	Business to Business
CAR	Corrective Action Request
CPQ	Configure Price Quote
ECO	Engineering Change Order
ECR	Engineering Change Request
ERP	Enterprise Resource Planning
HMLV	High-Mix Low-Volume
LC	Logistics Coordination
MES	Manufacturing Execution System
MTO	Make to order
MTS	Make to stock
OBF	Out of Box Failure
OPS	Operations
OTD	On-Time Delivery
OQC	Outbound Quality Control
PCM	Product Change Management
PDCA	Plan, Do, Check, Act

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1 Introduction

Constantly developing processes and their quality is the key to success in today's market. In recent years, more and more companies have strived towards more system-driven processes. A system-driven process should enable anyone with basic knowledge to perform their task without errors. This makes the company dependent on the system and not on its employees. It is easier for a system dependent company to continuously improve their processes because it is easier to find flaws in a system and fix it than to find flaws in employees and fix them. Other notable advantages that companies seek to achieve with system-driven processes include standardization which leads to consistent high-quality results, easier scalability and the possibility to utilize automation in the future. (Cheng 2010)

When the competition is fierce and the market is unstable, there is no room for making mistakes. This is why Vaisala wants to develop its processes and make it possible to continue and enable growth in the future as well. This means an increase in order volumes and the hiring of new employees. These are easier to implement with system-driven processes. In addition to this, system-driven processes make it possible to improve overall outbound quality and customer satisfaction requiring fewer resources for corrective measures. From this we can conclude that there is a need for a system-driven delivery process and the advantages of system-driven processes are well suited to Vaisala's current and future goals.

1.1 Background

The subject for this master's thesis was selected according to the development needs regarding the quality of Vaisala's current delivery process. Typically, the products arrive from the production to the freight packing area in marked product boxes. Thanks to this, the products are easy to identify, and their packing process goes smoothly without any difficulties. However, some more complex products come from production without product

packing and unmarked. In addition to this, identifying these products is also made difficult by the fact that the main structure includes all the other goods on the order, and they are not separately marked on the packing list. Due to these problems, there are too many mistakes, and the number of incoming customer complaints exceeds the target set by the company.

Vaisala's operating model is structured in accordance with Lean operating methods, and processes are therefore optimized to be as streamlined as possible. This can make it difficult to change the processes themselves or to add additional steps between different units of the delivery process. Also, the different systems in use and the limitations they set make it difficult to make changes at every stage of the process. The possible solution or solutions must be compatible and feasible with the current methods of operation and systems in use. In addition to this, changing the ERP system at the beginning of 2024 must not affect the functionality of the solution.

Today, Vaisala is the world's leading company specializing in weather, environmental and industrial measurements solutions. With more than 80 years of experience, Vaisala offers its customers reliable measurement solutions and services to support better decision making, safety and efficiency. All of Vaisala's measuring devices are made according to customer needs and only on order. Typically, the sales model used is Business to Business (B2B) and the manufacturing model is High-Mix Low-Volume (HMLV). These operating models are very commonly in make-to-order companies. (Vaisala Oyj 2022)

1.2 Structure of the thesis

The structure of this work can be divided into three parts: theoretical, empirical and conclusions. Main structure and its contents are presented in figure 1. down below. The theoretical part contains the necessary background information for the reader so that the main problem and its solution can be understood.

Figure 1 Structure of the report

The first chapter is an introductory chapter, where the operation of the system-driven process and its advantages are explained to the reader. In this chapter, the reader will go through the background of the work, i.e., why this work was done, what Vaisala does and how the problem to be solved by the work is reflected in Vaisala's operations. This chapter also presents the structure of the report as well as the research questions and objectives.

As seen in figure 1, this study continues with the theory part, where the delivery process is reviewed at a general level and then Vaisala's own delivery process, its principles, the systems in use and related problems and challenges are discussed in more detail. Chapter four reviews the causes of customer complaints and how they affect Vaisala's operations.

Chapter five deals with identifying problematic products and mistake proofing. Here using previous information, the current state of the problem, the root causes and how they could be corrected are investigated. The possible solution(s) found in this chapter are piloted and a comprehensive analysis of the piloting is made in chapter 6. After this, the possible follow-up measures are presented. Finally, here comes chapter 7 and 8 where the key results and conclusions are reviewed, and a summary of the whole work is presented.

1.3 Research questions and objectives

The aim of this study is to find correctable causes for incorrect shipments sent to customers and mistake proof them. The main objective is to research and test possible ways to mistake proof the delivery process of Vaisala weather factory products. Evaluate the benefits and disadvantages of these methods. And possible implementation of means/tools to reduce the number of incorrect orders received by customers. The testing phase includes a pilot in which, we examine the good and bad sides of the method, possible changes and agree on further measures.

Since the goal of the work only concern certain products, the work focuses especially on the processes, problems, and solutions of these products. Since the delivery process of the products in question differs from the norm and the basic things are difficult to implement, there is a very limited amount of literature available. As a result, a large amount of company

data, interviews and process monitoring are used to find a solution. The goal is achieved by finding answers to the research questions that can be seen below.

Main research question:

What are the correctable causes of incorrect shipments sent to customers and how can we mistake proof them?

Sub research questions:

What is the root cause of the problem, and can it be fixed?

What are the challenges facing the solution?

What are the possible solutions?

2 Product delivery process

There is fierce competition between companies for products and services. The biggest competitive factors are related to quality, speed, reliability, and price. These factors are mostly dependent on the quality of the processes included in the company's supply chain. Especially in the case of the manufacturing industry, every sub-process of the delivery process must be of consistent quality so that the end products can compete with other similar ones. The delivery process produces a huge amount of information, and all that information is necessary and must be able to be stored and analyzed as efficiently and accurately as possible. With the help of this information, the aim is to direct the goods from one place to another as efficiently as possible, aiming for the customer to receive a high-quality product according to the agreed schedule. (Wang et al. 2011)

In this theory section, important theory from different areas of the delivery process is reviewed. In the delivery process, the emphasis is on the order-delivery process model, which is used by the target company. At the same time, however, the parts that belong to the initial stage of the process are cut out and the focus is completely on the parts that are essential for the work, i.e., production, packaging, and transportation.

2.1 Problems and challenges

Product delivery processes contains all kinds of challenges. To make the process work as seamlessly as possible, these challenges must be taken into account when planning and developing the flow of the process. The challenges in this area are reducing costs, i.e., increasing the efficiency of production and logistics own processes, as well as improving quality. Additional challenges for the delivery process are also created by adapting to the operating environment and changes in corporate strategy. (Sweet & Bali Swain 2021)

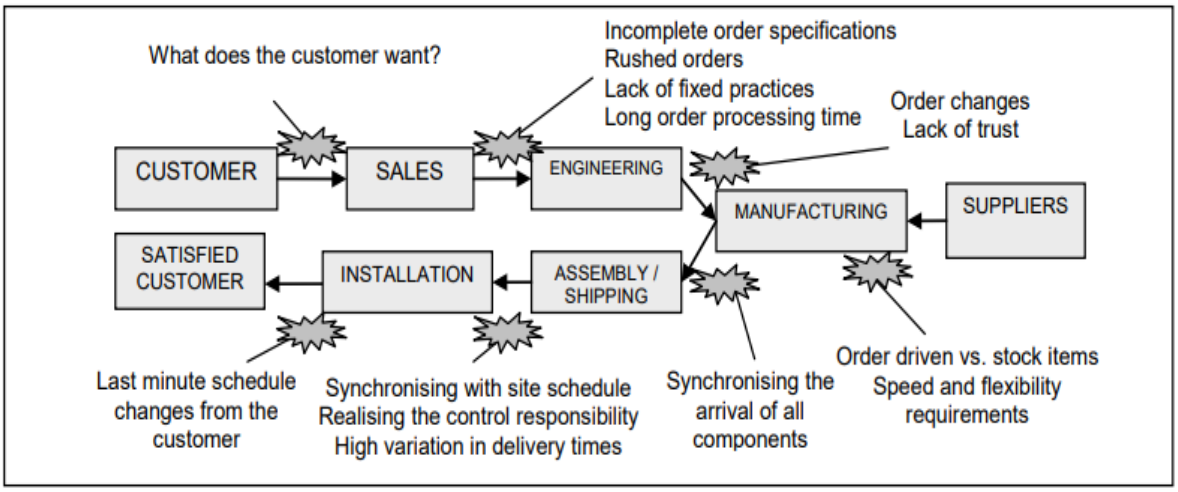


Figure 2 The problems of order-delivery process (Iskanius & haapasalo 2003)

As you can see in Figure 2, problems occur especially between different units of the supply chain. The picture presents a basic order-delivery process, but in this work, we only focus on the operational side of the delivery process, i.e., the manufacturing phase and all subsequent phases. Problems also occur within different sub-processes, and they can be related to forecasts, orders, or implementation. Forecasts may be off due to poorly made forecasts, demand fluctuations or incorrect metrics. (Iskanius & Haapasalo 2003)

Comprehensive challenges such as quality, meeting delivery times and costs apply to every stage of the delivery process. The right number of workers and all the necessary parts must be available for production in time, so that the production can be started according to the schedule. Rushing at any stage of the process can lead to poor quality or late delivery. To ensure the quality of the manufactured product, in addition to competent and sufficient personnel, the systems and instructions must also be up to date. The same also applies to other stages of the process. To achieve a smoothly proceeding delivery process, the sub-processes must work in sync with each other. Even if everything goes smoothly at the factory and the packing/shipping area, the customer can demand last minute changes to the product or its shipping schedule. Companies should be prepared for possible changes, and their successful implementation often leads to a good customer experience and thus increasing order volumes in the future. (Sweet & Bali Swain 2021)

The future challenges of the delivery process are mainly caused by external factors. Especially during the pandemic, there was a shortage of components and transportation, at the same time the restrictions caused by the war and the sudden rise in the price of electricity created uncertainty in the market. This makes it difficult for manufacturing companies to operate and poses challenges especially for companies struggling with profitability. At the same time, the cost of living has increased, and this leads to an increase in salary expectations of employees, which makes it even more difficult for companies to make a profit in the future. A shift towards more environmentally friendly operations is often seen as a way to create a competitive advantage, but at the same time the additional costs it causes must be taken into account. This should be properly prepared because in the end, when possible sanctions come, companies making the transition may have to fight to make the operation more sustainable and at the same time keep it profitable. (Stark et al. 2017)

2.2 Information management

The entire supply chain must be managed and controlled. The goal of management is to increase sales, reduce costs, improve the quality of processes, and use the company's resources as well as possible. In supply chain management solutions, all stakeholders are connected, and the aim is to examine the processes as a whole. The goal is always a more satisfied end customer. Various systems and programs are a key factor in the collection of critical information, which makes it is easier to start developing processes. (Wang 2015)

Information quality has become a critical factor in companies. The growth of data warehouses and the direct use of data from different sources have created a growing need in companies to measure and manage data quality. Information systems researchers have always considered the quality of information to be one of the critical factors in terms of business operations. In industry, the quality of information has come to the fore, especially in connection with increased data warehouse projects. (Wang 2015)

2.3 Order-driven delivery process

The delivery process is divided into two main groups: make to stock (MTS) and make to order (MTO). The difference between these is the time of manufacturing of the goods compared to the incoming order. In the MTS model, goods are made in advance to the warehouse and when the order arrives, it is sent from the warehouse to the customer. On the other hand, in the MTO model, the production of the goods starts only after the order is placed by the customer. The basic areas of the delivery process are manufacturing, testing, packaging, and delivery. Based on these different basic elements of the delivery process, the company builds a delivery process that best serves its customers and their wishes. (Gunalay 2011)

If the products are such that it is not profitable to prepare them in advance and store them, they must be prepared only after the order. Producing, assembling, and planning the order, which often also includes manufacturing the product either by oneself or with the help of subcontractors, are typical features of order-driven delivery process. Contrary to warehouse-driven delivery processes, in order-driven delivery processes production and logistics measures are taken only after the customer's order. When it comes to a highly customized or capital-intensive product, it should not be produced in advance. Therefore order-driven delivery process is mostly used in companies that produce small-volume non-standard products, while mass products are mostly warehouse-driven. (Gunalay 2011)

2.4 Transportation

Transportation forms an important part of the delivery process. As lead times shorten, customer service improves and distribution routes become more direct, goods are transported more often in smaller batches. What is important is the development of the service level and quality, as well as the improvement of transport control and goods handling. The goal of

developing the transport service level is mainly to generate added value for customers and, of course, to develop and improve delivery reliability and punctuality. Added value can be achieved in many other ways. Delivery times based on customer needs, unloading products directly at points of use and reducing packaging are factors that generate added value. The importance of added value is emphasized even more as competition intensifies, and that brings with it many specialized distribution networks to replace general transport systems. (Bookbinder 2012)

Packing the product is an important part of the transporting event. Especially in an export situation, the packaging must protect the product well and withstand the stresses caused by transport and possible reloading. The packaging should take up little space and at the same time be as durable as possible. The quality of the product, the length of the transport distance and the selected transport method affect the choice of packaging. Nowadays, the recyclability of the packaging material and the environmental damage caused by the mode of transport should also be considered, as it is important for more and more companies to cooperate only with companies that promote sustainable development. (Merkert & Hoberg 2022)

Transportation and logistics are the most outsourced functions of companies. Uncertainty about the level of services and the possibility of controlling them is seen as the biggest obstacle to outsourcing. Another concern is whether these actions will result in cost savings. The same reason often also acts as a motivator because tendering for transport or the entire logistics is often seen as a way to create cost savings. However, the most important reason for outsourcing is the desire to focus on core competence and the desire for operational flexibility. Today, more and more often, the goods must arrive at the customer's location as quickly as possible or by a certain time. This makes it difficult to plan transports and at the same time the full load principle does not work for many companies' transports. That's why transporting is often outsourced, so that the customer can be offered a suitable transport method and time. When outsourcing, it is always important to think about quality, functionality, flexibility, expertise, controllability, and risks alongside costs. Finding reliable partners is the key to happiness. (Bookbinder 2012)

2.5 Delivery process metrics

Measurement is needed in companies to find out where they are right now and where they are going. In the delivery process, the metrics can be divided into production and delivery sub-processes. The desired goals and metrics of the entire process are also determined separately. Metrics are needed for guidance, communication, and monitoring of change, to support supervision and decision-making, to analyze learning, reward and encourage. Based on the data provided by the meters, it is possible to identify weaknesses in the process, implement corrective measures and monitor the progress of the changes made. Things should be easily measurable, and the information produced by the meters should be comprehensible and reinforce the desired behavior. The metrics must be connected to the strategy and mission. It is also important that the personnel understand the indicators and their uses and are able to distinguish between good and bad performance. (Cecere 2015)

In this work, two critical metrics used by the target organization are reviewed: reliability of delivery and customer feedback. These metrics affect everything that is done in production and logistics and support their development.

2.5.1 Reliability of delivery

Delivery reliability is a two-way deal. The product to be sent to the customer must be completed on time so that it can be sent to the customer according to the schedule. At the same time, the selected transport company must reliably deliver the goods to the customer within the agreed schedule. This gives the customer confidence in the delivery times offered by the company, which makes it easier to order goods in the future. Too often suppliers try to improve their delivery reliability by extending delivery times. This might work as a temporary solution but should not be a permanent solution unless something changes in the process that slows it down. The waiting time included in the delivery time increases at the

same time as the delivery times are extended, because of which there will be more changes to the delivery than before. The supplier often has many other open orders, which makes production control difficult. In the worst case, deliveries start to be prepared too early, which is why the cost of storing and changing finished products only increases. At the same time, due to the lack of urgency to get through the item, other more urgent work can be put before it, and eventually the item will be late despite the long delivery time. (Cecere 2015)

Delivery times and delays are key monitoring targets in order-driven supply chains. With the help of delivery time accounting, the aim is to predict order-delivery delays for raw materials and components and to build lasting lead times for customers. Often the delivery times of raw material components or subcontracted goods are too long in relation to the customer's delivery time requirements. In these cases, the company itself stores the necessary raw materials, components, or intermediate and final products, so that it can better meet the needs of its customers. (Cecere 2015)

2.5.2 Customer feedback

The goal of all business is a satisfied customer. To achieve, maintain and develop customer satisfaction, the quality of the products and service must be in good condition. This requires the functioning of each sub-process as part of the entire delivery process. Effective processes lead to good quality, which improves customer satisfaction and creates a competitive advantage in the market. For the processes to operate at the desired level of certainty, they must have functioning systems, routines and instructions supporting the employees. (Morgan & Rego 2006)

The systematic collection and analysis of customer feedback offers companies the opportunity to develop products and processes. Positive and negative feedback is just as important for companies. It is worth focusing on both and using the positive feedback to

identify where you have succeeded well and to repeat the activities leading to such feedback. On the other hand, from negative feedback, it is possible to identify the causes that led to errors and thereby various development targets, based on which it is good to start improving processes. Emphasizing the quality of operations and its continuous development is seen as a critical factor for the company's success in the competitive market. Data obtained from customer feedback should be used as support here. The customer feedback received at the same time serves as a measure of the company's operations and the level of market requirements. (Morgan & Rego 2006)

2.6 Quality management

Quality might be the most complex and important part of corporate strategy. Companies compete on quality while customers are looking for quality. So, quality has the power to change the market. Because of this, quality management plays a very central role in companies' strategies. Quality management can be seen as different ways and tools used to achieve high-quality products and services. This means that quality management methods are often used to improve the quality of processes leading to the final product or service. (Golder et al. 2012)

Many companies use quality management tools that enable monitoring the quality of the work and the result at different stages of the delivery process. The set standards and goals are used as the basis for the desired quality. In this way, employees have a clear picture of what is required of them at any stage of the work. The monitoring of realized quality is often done system-controlled, but in some cases a separate manual quality check can be a more effective way to ensure quality. However, systems and inspections alone are not enough to guarantee good quality. Continuous communication and improvement are often seen as decisive factors for the success of quality management. (Mellat-Parast 2013)

2.6.1 Mistake proofing

One method of achieving the desired quality is mistake proofing. Poka-yoke, also known as mistake proofing, is a Lean method where a company is using different devices to eliminate human error from their processes, making their processes more productive and profitable while improving overall quality and customer satisfaction. These poka-yoke devices are mechanisms that either prevents the mistake from happening or makes the mistakes obvious immediately. These devices are usually cheap and often appear as reader devices + QR-/barcodes, sensors or go/no-go gauges. (Dudek-Burlikowska & Szewieczek 2009) Finding mistakes immediately is valuable because it follows that mistakes will not turn into defects if worker errors are discovered and eliminated beforehand (Shingo 1986, 50).

The basic idea of mistake proofing is to build the processes in such a way that the systems and operating methods in use do not allow mistakes to be made. This mode of operation is very common, especially in companies with low-volume and mixed production. Statistical quality control methods are more difficult to implement in these companies due to the lack of a large sample size. Mistake proofing requires a new approach to production and logistics. But when decision makers have learned to recognize mistake proofing tools, their new way of thinking enables them to notice numerous mistake proofing opportunities. Some of the changes may even require very small investments, but other mistake proofing operating models may require changes to all stages of the process or even to the systems in use. (Tommelein 2008)

3 Vaisala delivery process

Delivery process can be interpreted in many different ways. According to Russell (2021) delivery process is a set of steps that allows you to deliver a product from an initial idea to the end user. In make-to-order delivery processes this means all the steps between the customer order and delivery. Different delivery processes have distinct goals. For example, many processes delivering highly standardized products, the requirements set a high priority for low costs and short response time. On the other hand, in processes where complex and unique products are made according to customers' wishes, the focus is usually on the quality of the goods and delivery. (Kallio et al. 2000, 75)

Make-to-order companies manufacturing non-standard products often faces problems during the order-delivery process. Most of the problems exist at the interfaces between units of the chain. This includes synchronizing the arrival of all components and labeling them correctly. (Iskanius & Haapasalo 2003, 10) Different units understanding of other units needs and skills may vary considerably. For example, a factory worker may find that a tag attached to a cable is useless, but in a packing, it could be needed for product identification.

In this chapter we examine the operation of Vaisala's delivery process and how it differs from the general perspective. After this the principles and goals related to the delivery process will be reviewed. We also study the systems in use and their impact in different stages of the process. Common problems and challenges occurring during the delivery process and why it is difficult to change are also presented.

After these the reader should have a general understanding of Vaisala's delivery process and why it works the way it does. This will help the reader to understand the main problem and the possible solutions in the later stages of this study, as well as the challenges related to these solutions.

3.1 Current state

Every Vaisala product is produced according to the customer's needs and therefore as shown in figure 3 Vaisala's delivery process begins with an order received from the customer. The customer, salesperson and production planners agree on a suitable delivery time for the goods, after which the order is entered into the ERP system, where it is transferred to the production work queue. Delivery times vary from three days to several months depending on the product. This is not always due to manufacturing times, but also to material availability.

In the next step of the process, the product is manufactured. Manufacturing times also vary considerably depending on the product. Simple products can be produced hundreds per day, but larger and more complex products can take several weeks to produce. Some of the products go through a final inspection (OQC) after manufacturing. The final inspected products are determined by the frequency of defects that has been occurred in them. The final inspection points are connected to the production cells, so that the goods are transported as little as possible, avoiding waste.

From production, the products are transported to the organizer either to the courier packing area or the freight packing area. Most of the weather factory products are shipped from the freight packing area, and that is why we will focus on that in this work. The freight packing area organizer moves the arrived goods to the shelf according to the order number. Some of the goods coming in carts, such as RWS200 (Road Weather Station), are kept in their respective carts until the packaging process. The goods are then moved to be packed when all the goods belonging to the order have been organized by the organizer or when the promised shipping date arrives. There are exceptions to this as well, depending on whether the customer wants the order in partial deliveries or not and whether the customer has given permission to ship the order before the agreed shipping date.

In the packing area, the product is packed, and a delivery is made to the ERP system. At this point, the packer makes sure that all the items on the packing list goes into the box or boxes. The packer then sends the delivery information and the packing list by email to the LC team and the box/boxes are moved to the packed area. The LC team agrees on the transport with the transport company and takes care of the shipment documents, after which they ship the shipment from the ERP system and delivers the order documents and labels to the freight packing area. When the order's documents and labels arrive, they are attached to the correct order's box/boxes and the boxes are moved to the loading area to wait for the transport company to pick them up. After this, the transport company picks up the order and delivers it to the customer.

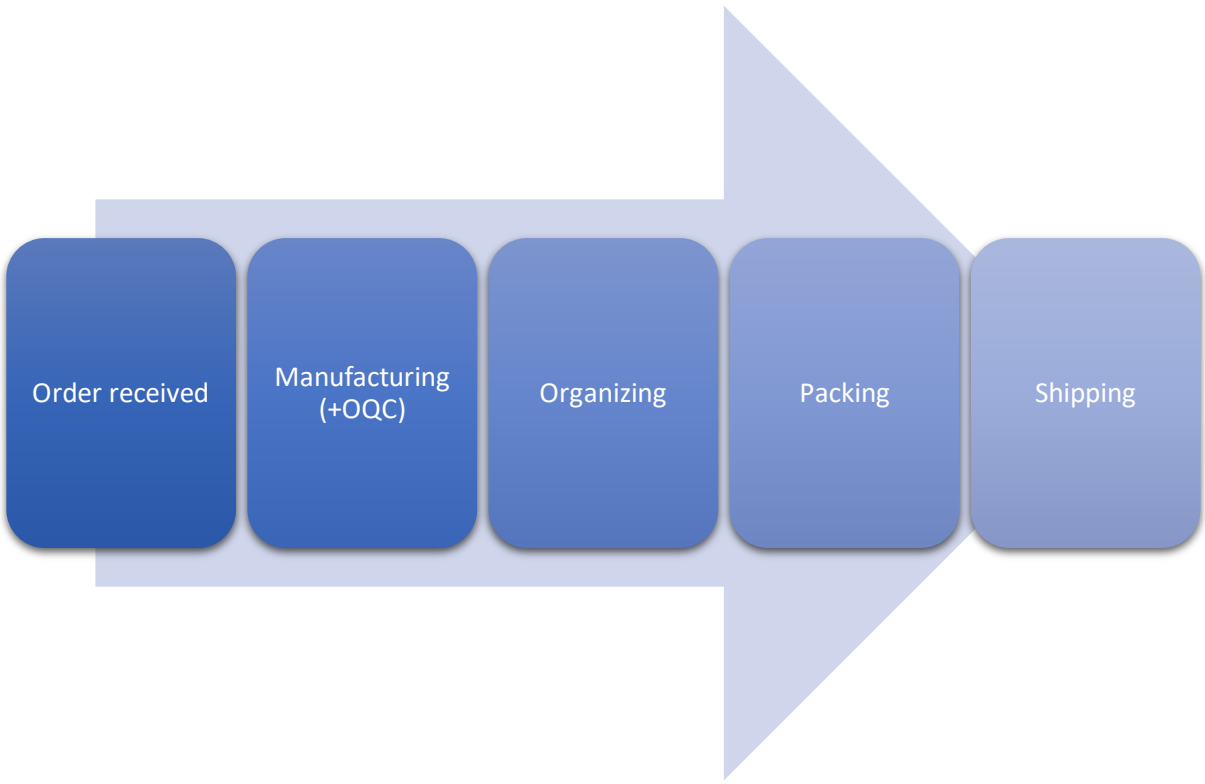


Figure 3 Vaisala Delivery Process

3.1.1 Principles and goals

Vaisala's delivery process is shaped according to the principles of Lean. The idea behind everything is to minimize waste and maximize productivity. Efforts have been made to create the entire process as streamlined as possible, so that productivity would improve without compromising in quality. The goal is to achieve satisfied customers and create mutual, lasting benefit. (Vaisala 2022a)

The quality and productivity of production and logistics is monitored using various metrics. General and team specific bonuses are based on these results, the purpose of which is to support improved productivity and encourage employees to pay more attention to what they are doing. General bonuses impacting the entire operations team are OTD (on-time-delivery) and OBF (Out of Box Failure). The maximum bonus is achieved when 97% of the orders are shipped on schedule and OBF errors revealed from customer complaints are in less than 0.4% of all shipped orders. Team specific bonuses cover productivity and outgoing quality control deflect rate on the manufacturing teams. On the logistics side, the bonuses emphasize OTD and OBF in particular, but in addition to these, packing speed and inventory accuracy are also monitored.

3.1.2 Systems

Vaisala has different systems in use that work in connection with each other. In this chapter, we go through the phases in which the different systems affect and how. Various lists that are important for the process are also presented. When the customer wants to order a product, they and the seller go through a product specific order form similar to Figure 4, where the products various customization options and add-ons are reviewed. Once the configuration code has been agreed upon, the seller forwards the information to the order management specialist, who enters the order into the ERP system.

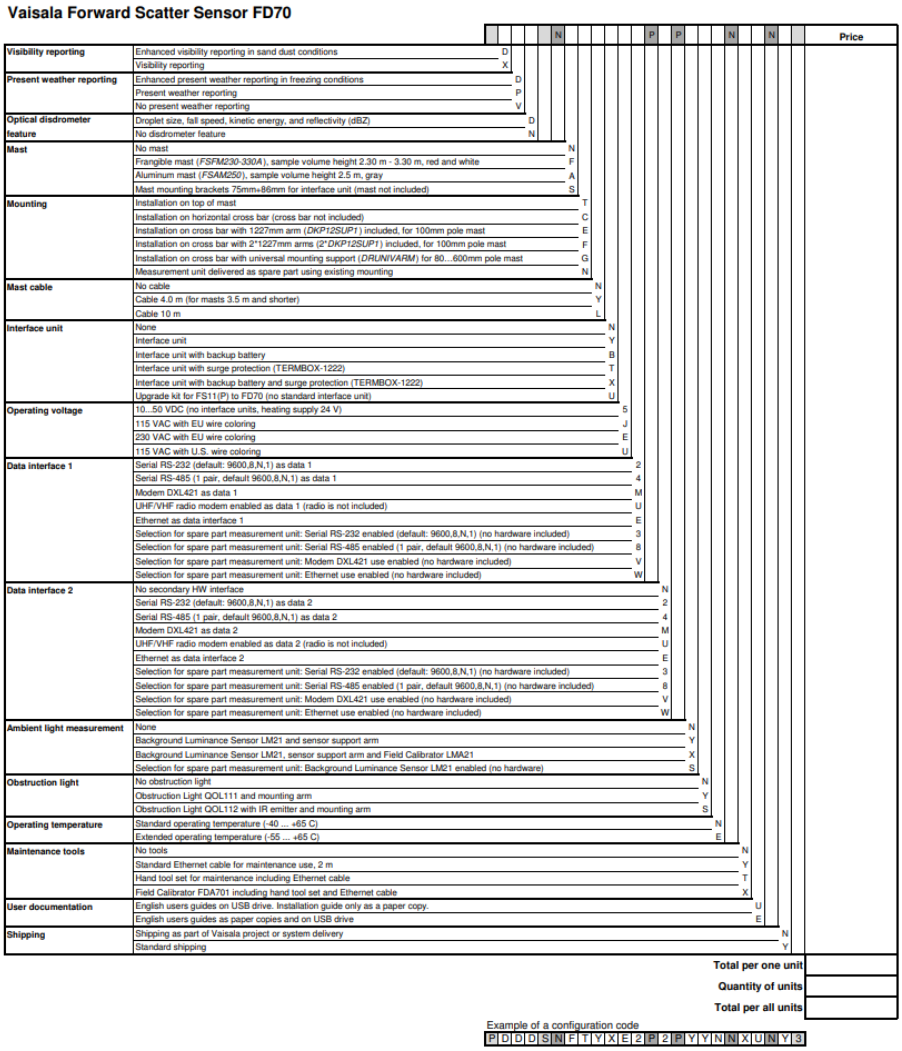
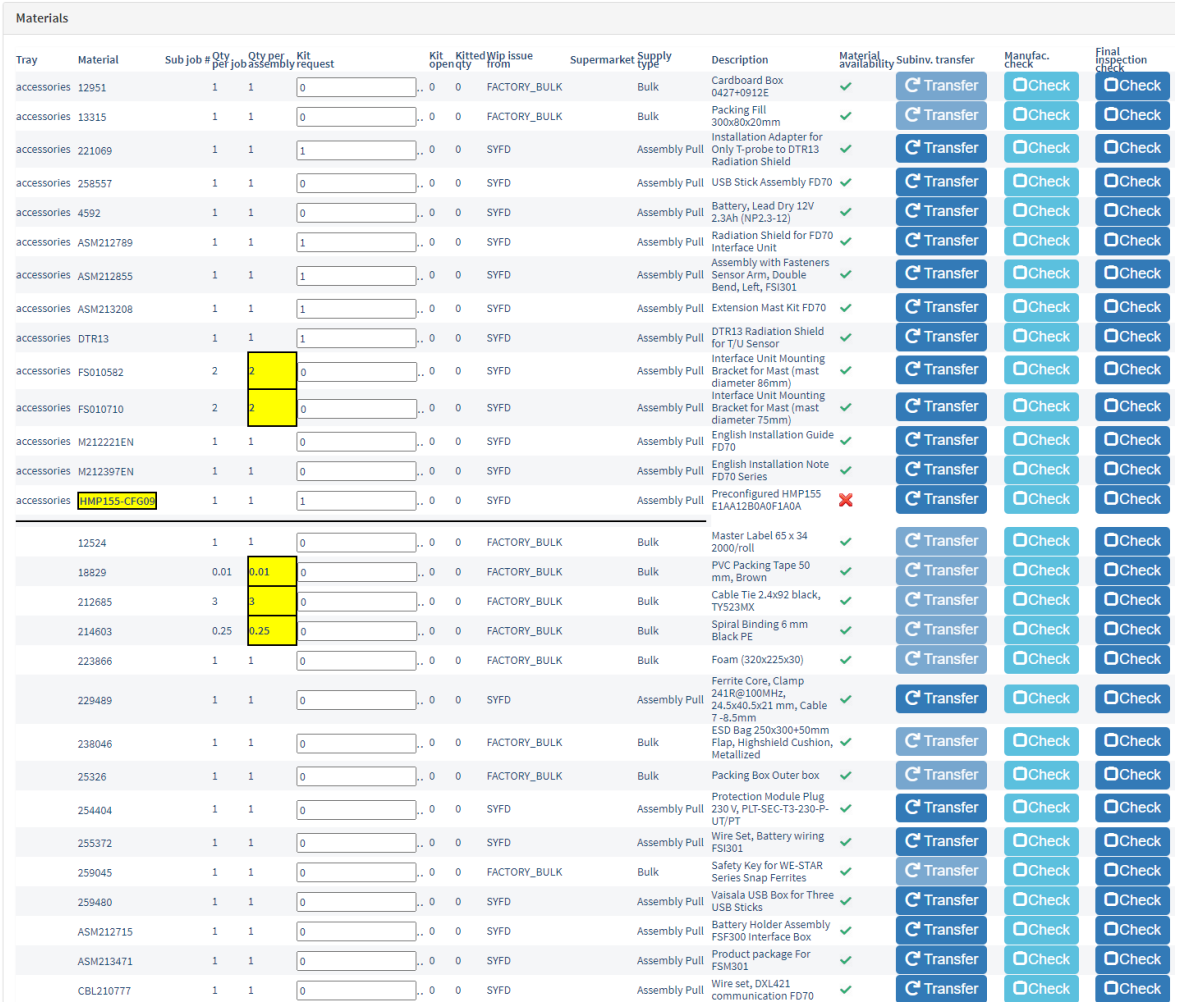


Figure 4 FD70 Order Form

The order from the ERP system is automatically integrated into the Planet system, where it appears in the production work queue. At this stage, production planners check the order information (ERP/Planet) and release it to production for processing. When the order comes next in the work queue, the production employee opens the job attached to the order (figure 5), which shows all the materials and accessories going to this product. This can also be printed as a paper version and some operators prefer it that way. The job list shows all items belonging to that one line. Some of the goods go into the product itself and some, e.g. cables, remain outside it as loose components. After the product is manufactured, the production employee changes the order status to “picked” in the ERP system and sends it forward.



Materials

Tray	Material	Sub job #	Qty per job	Qty per assembly	Kit request	Kit open	Kitted qty	Wip issue from	Supermarket	Supply type	Description	Material availability	Subinv. transfer	Manufac. check	Final inspection check
accessories	12951		1	1	0	0	0	FACTORY_BULK		Bulk	Cardboard Box 0427+0912E	✓	Transfer	Check	Check
accessories	13315		1	1	0	0	0	FACTORY_BULK		Bulk	Packing Fill 300x80x20mm	✓	Transfer	Check	Check
accessories	221069		1	1	1	0	0	SYFD		Assembly Pull	Installation Adapter for Only T-probe to DTR13 Radiation Shield	✓	Transfer	Check	Check
accessories	258557		1	1	0	0	0	SYFD		Assembly Pull	USB Stick Assembly FD70	✓	Transfer	Check	Check
accessories	4592		1	1	0	0	0	SYFD		Assembly Pull	Battery, Lead Dry 12V 2.3Ah (NP2.3-12)	✓	Transfer	Check	Check
accessories	ASM212789		1	1	1	0	0	SYFD		Assembly Pull	Radiation Shield for FD70 Interface Unit	✓	Transfer	Check	Check
accessories	ASM212855		1	1	1	0	0	SYFD		Assembly Pull	Assembly with Fasteners Sensor Arm, Double Bend, Left, FSI301	✓	Transfer	Check	Check
accessories	ASM213208		1	1	1	0	0	SYFD		Assembly Pull	Extension Mast Kit FD70	✓	Transfer	Check	Check
accessories	DTR13		1	1	1	0	0	SYFD		Assembly Pull	DTR13 Radiation Shield for T/U Sensor	✓	Transfer	Check	Check
accessories	FS010582		2	2	0	0	0	SYFD		Assembly Pull	Interface Unit Mounting Bracket for Mast (mast diameter 86mm)	✓	Transfer	Check	Check
accessories	FS010710		2	2	0	0	0	SYFD		Assembly Pull	Interface Unit Mounting Bracket for Mast (mast diameter 75mm)	✓	Transfer	Check	Check
accessories	M212221EN		1	1	0	0	0	SYFD		Assembly Pull	English Installation Guide FD70	✓	Transfer	Check	Check
accessories	M212397EN		1	1	0	0	0	SYFD		Assembly Pull	English Installation Note FD70 Series	✓	Transfer	Check	Check
accessories	HMP155-CFG05		1	1	1	0	0	SYFD		Assembly Pull	Preconfigured HMP155 E1AA12B0A0F1A0A	✗	Transfer	Check	Check
	12524		1	1	0	0	0	FACTORY_BULK		Bulk	Master Label 65 x 34 2000/roll	✓	Transfer	Check	Check
	18829		0.01	0.01	0	0	0	FACTORY_BULK		Bulk	PVC Packing Tape 50 mm, Brown	✓	Transfer	Check	Check
	212685		3	3	0	0	0	FACTORY_BULK		Bulk	Cable Tie 2.4x92 black, TY523MX	✓	Transfer	Check	Check
	214603		0.25	0.25	0	0	0	FACTORY_BULK		Bulk	Spiral Binding 6 mm Black PE	✓	Transfer	Check	Check
	223866		1	1	0	0	0	FACTORY_BULK		Bulk	Foam (320x225x30)	✓	Transfer	Check	Check
	229489		1	1	0	0	0	SYFD		Assembly Pull	Ferrite Core, Clamp 241R@100MHz, 24.5x40.5x21 mm, Cable 7 -8.5mm	✓	Transfer	Check	Check
	238046		1	1	0	0	0	FACTORY_BULK		Bulk	ESD Bag 250x300+50mm Flap, Highshield Cushion, Metallized	✓	Transfer	Check	Check
	25326		1	1	0	0	0	FACTORY_BULK		Bulk	Packing Box Outer box	✓	Transfer	Check	Check
	254404		1	1	0	0	0	SYFD		Assembly Pull	Protection Module Plug 230 V, PLT-SEC-T3-230-P-UT/PT	✓	Transfer	Check	Check
	255372		1	1	0	0	0	SYFD		Assembly Pull	Wire Set, Battery wiring FSI301	✓	Transfer	Check	Check
	259045		1	1	0	0	0	FACTORY_BULK		Bulk	Safety Key for WE-STAR Series Snap Ferrites	✓	Transfer	Check	Check
	259480		1	1	0	0	0	SYFD		Assembly Pull	Vaisala USB Box for Three USB Sticks	✓	Transfer	Check	Check
	ASM212715		1	1	0	0	0	SYFD		Assembly Pull	Battery Holder Assembly FSF300 Interface Box	✓	Transfer	Check	Check
	ASM213471		1	1	0	0	0	SYFD		Assembly Pull	Product package For FSM301	✓	Transfer	Check	Check
	CBL210777		1	1	0	0	0	SYFD		Assembly Pull	Wire set, DXL421 communication FD70	✓	Transfer	Check	Check

Figure 5 Example of a Wip Job view

The more complex products are tested in production, after which the operator transfers the goods to a box or cart, from where it goes directly to the freight packing area or to the final inspection point (OQC). The products that are selected for the OQC inspection process are determined based on the errors that appeared in them. A sufficiently large number of customer complaints about a certain product lead to its 100% final inspection. When a certain amount of the product in question has gone through the final inspection without any detected defects, its inspection percentage is decreased and the same continues until it is determined that there is no longer a need for a final inspection for this product. On the other hand, if a defect is detected in even one product, its final inspection percentage will be raised back to 100%. In its inspections, OQC uses the job list and separate product specific work instructions, which contain pictures of different products and their optimal condition.

Finally, the goods arrive at the freight packing area, where the organizer looks at which order and which lines it contains and sorts the goods based on that. At the same time, the organizer will mark the status of the order on the planet to “In Organizing” or “Ready for packing” depending on whether the order can already be sent and whether all the goods have already arrived. After this, the goods are moved to the packing area, where the packer checks the packing list that all the necessary goods are on order and creates a delivery for it in the ERP system. Then the packer communicates with the LC team via email and finally the order is closed from the ERP system. During the entire final process, the status of the order automatically changes in the integrated Planet system from "In packing" and "Ready for shipping" to "Waiting for pickup".

The ERP system is at the center of the whole process and its operation is mainly supported by the planet system integrated into it. The current ERP system in use is very old and it will change to a newer one at the beginning of 2024. Because of this, it is not able to take handle of all phases of the process, and different pieces of paper must be used to complete it. The systems in use are therefore do not prevent mistakes from being made and that is why we need a way to ensure the functionality of the process.

3.1.3 Problems and challenges

Vaisala’s delivery process is constantly being developed and demands from different directions are consistently changing the operating methods. For this reason, the processes can be very complex for some products, and it brings with it additional challenges when something needs to be changed or improved again. None of the current systems prevent errors from occurring. The packer may pack completely the wrong products in the wrong box, or pack extra items or even boxes for orders. There are no alarms from this, but the outbound team completely trusts the professionalism of their workers and the contents of packing lists. It’s complicated by the fact that packing list doesn’t always list all the products separately, but for some products, all the items belong to the main product.

Employees have long careers on average, so the know-how is good. Currently Vaisala relies too much on these professional skills of its employees and many things are completely dependent on the employees' memory. Because of this the process is exposed to human errors. More system-driven processes are needed so that the delivery process is not so dependent on the skill level of the employees. The introduction of a new ERP system may enable improvements towards more system-driven processes, but at the same time all add-ons integrated into the current ERP system, such as Planet, will be taken out of use. Therefore, the solution must not be system dependent, and should work regardless of which ERP system is in use.

The delivery process has been made very streamlined by utilizing Lean operating methods. This makes it difficult to change, and the possible additional work added into it breaks the continuum and creates a bottleneck. This excludes some of the possible solutions, as slowing down all operations for a small quality improvement is not reasonable. Experienced employees' resistance to change and the bonus system in use and the efficiency measures it contains also make it difficult to implement an operating method. For these reasons, the solution must be the easy to implement and its use must not complicate or slow down current activities.

3.1.4 Quality management

Quality Management is how we apply the theories, principles, and practices associated with the defining, creating, and delivering of products and services that generate value for our customers (Kenyon & Sen 2015, 1). The overall goal is to meet and exceed customer's needs. In order to exceed customer expectations, a high-quality end product alone might not be enough, but the value received by the customer must also be increased in other ways, such as fast delivery and good service. These can only be achieved consistently with high-quality processes. In particular, a high-quality product and fast delivery go hand in hand with a high-quality delivery process. (Kenyon & Sen 2015)

Many of Vaisala's weather factory products are complex, and one of the biggest selling points is the good quality of the end products. This creates a competitive advantage in the measuring device market, where one of the most important competitive factors is product quality, where the biggest factors are the accuracy of the measurement results, the durability of the product and the adaptability according to the customer's needs. In order to maintain a competitive advantage and increase its market position, Vaisala must invest in the quality of the processes, because the quality of the final product is completely dependent on the quality of the process it went through. Better processes lead to better results, which increases customer satisfaction. (Kenyon & Sen 2015)

Poor or variable quality causes additional costs in addition to a decrease in customer satisfaction. If there is a defect or deficiency in the product sent to the customer, Vaisala will manufacture and send replacement goods to the customer as quickly as possible and free of charge. In addition to this, the process resulting from a customer complaint and the subsequent corrective measures consume resources from several different departments. Quality problems detected in production, at the final inspection point (OQC) or in the freight shipping area also lead to corrective measures and in the worst case the entire product must be scrapped and manufactured again. This will most likely lead to the shipment being delayed from the agreed delivery time, which will reduce customer satisfaction.

Vaisala's delivery process is divided into different parts, and each part has its own responsible person. This person's job is to maintain and improve the quality of that process and ensure its functionality. Process engineers are responsible for the productions process and the logistics process team is responsible for the processes on the logistics side. In addition to these, the production teams and the quality team (OQC) are responsible for the quality of the end products. In an ideal situation, the production teams should only manufacture the products according to the process and the quality team would not be needed at all. However, the processes are not yet fully system-driven, and errors can occur in them without the system alerting or preventing their occurrence. This is a major point of development for which we are trying to find solutions.

The development of process quality is currently very strongly dependent on responsiveness. Based on customer complaints, corrective measures are taken. A problem is identified from each customer complaint and an effort is made to find its root cause. If the root cause can be identified, a person is appointed to start a project aimed at correcting the root cause in order to avoid future errors. These projects are directed to the person in charge of the relevant area. Errors noticed at the factory and in logistics are also reacted to in the same way. Different customer experience measurements are also used to track customer satisfaction and possible areas of development. All these measures are taken to make customers as satisfied as possible and to avoid additional costs caused by poor quality.

3.2 Improving delivery process quality

Now that the current state of the delivery process, the challenges it contains and the quality management measures in use are known, we can start the work related to the project itself. The project begins by examining the data available on customer complaints and thereby aims to identify the reasons that led to incorrect orders sent to customers. The process of handling customer complaints and the harm caused by them will also be reviewed to create an understanding of the possible benefits of improving quality. After this, the aim is to identify all weather factory products with the same risk. For these products, every step of the process is examined and the steps where errors can occur are identified.

Once the problematic products have been identified, the requirements and restrictions that influence the choice of the solution method are reviewed. After this, the purpose is to present and compare different solution options and choose the most suitable one for the piloting phase. The piloting of the chosen solution option is started when the pilot's objectives have been determined. At this stage, the functionality of the solution and how it meets the goals set by Vaisala are examined. At the same time, we strive to get a clearer picture of how incorrect orders sent to customers can be prevented at different stages of the process. After the pilot, its results are reviewed, and further measures are decided based on these results.

The goal at this stage is to get a full understanding of how to really solve the problem of incorrect orders sent to customers. Then come the conclusions, which answer the research questions set at the beginning of the work and presents the results of the work. Finally, a summary is presented, which goes over how the work was carried out from start to finish.

4 Customer Complaints

In the context of the manufacturing industry, a customer complaint refers to a situation where the company does not meet the customers' expectations regarding the product or its delivery. Due to today's highly competitive market, the stakes are higher and customer expectations have grown and they have become more demanding. This increases the importance of continuous assessment to define elements that satisfy customer needs and increase future sales. (Ahmed et al. 2020)

Companies spend substantial resources responding to customer complaints. Prompt and correct response is believed to increase customer loyalty. With a successful customer complaint handling process, the customer will be satisfied and will probably order again, even if there was reason to send a customer complaint in the first place. (Morgeson et al. 2020)

Answering and reacting to complaints is important, but it is equally important to familiarize yourself with the reasons for the complaints, especially if there are many complaints about the same subject or product. Companies can learn a lot from customer complaints by getting familiar with the factors that have led to these received customer complaints. With the help of data obtained from customer complaints, the company can identify errors and their frequency in its own processes. (Janda et al. 2021) This supports the development of processes and can lead to development projects, such as this thesis.

This chapter introduces Vaisala's customer complaints process. How are they processed and how they are sorted. The most common reason is reviewed, and the root cause analysis for this will be done. The waste caused by customer complaints and its effect on the operation of the entire factory is also presented.

4.1 Vaisala customer complaints

A customer complaint is defined as any notification of concern or expression of dissatisfaction from a customer in the quality of a product, project or service delivered by Vaisala (Vaisala 2022b). This could include missing or damaged parts in a delivery, poor quality packaging in a delivery, a failure of a product to meet promised performance expectations or specifications, poor quality customer service, poor speed of response or resolution and poor project management or failure to meet contractual obligations.

Without a formal customer complaint process they might be handled in an inconsistent way and without the opportunity to correct or improve recurring problems in our processes. Vaisala's customer complaint handling process is presented in figures 6 and 7. It consists of CARE process and the CAR (Corrective Action Request) process. This provides a structured way of working and escalation. CARE process includes all the immediate customer facing actions with the goal of ensuring a fast solution to the customer's problem. In the CARE process, the problem is identified, and the corrective measures required by the customer are implemented. The biggest benefits of CARE process are case traceability and customer relationship management.

After the complaint is received and the problem is identified a CAR issue is done and possible corrective actions will be analyzed. During the CAR process the problem is described and forwarded to the relevant department. There, the problem is reviewed, and an effort is made to find the root cause and to come up with corrective actions. The goal of the CAR process is to prevent recurrence of the problem by using a systematic problem-solving approach.

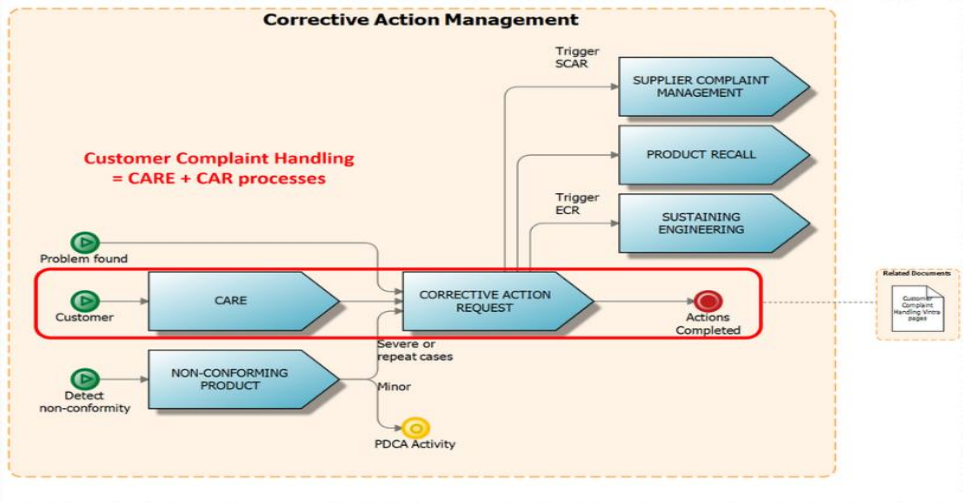


Figure 6 Customer Complaint Handling Process (Vaisala 2022b)

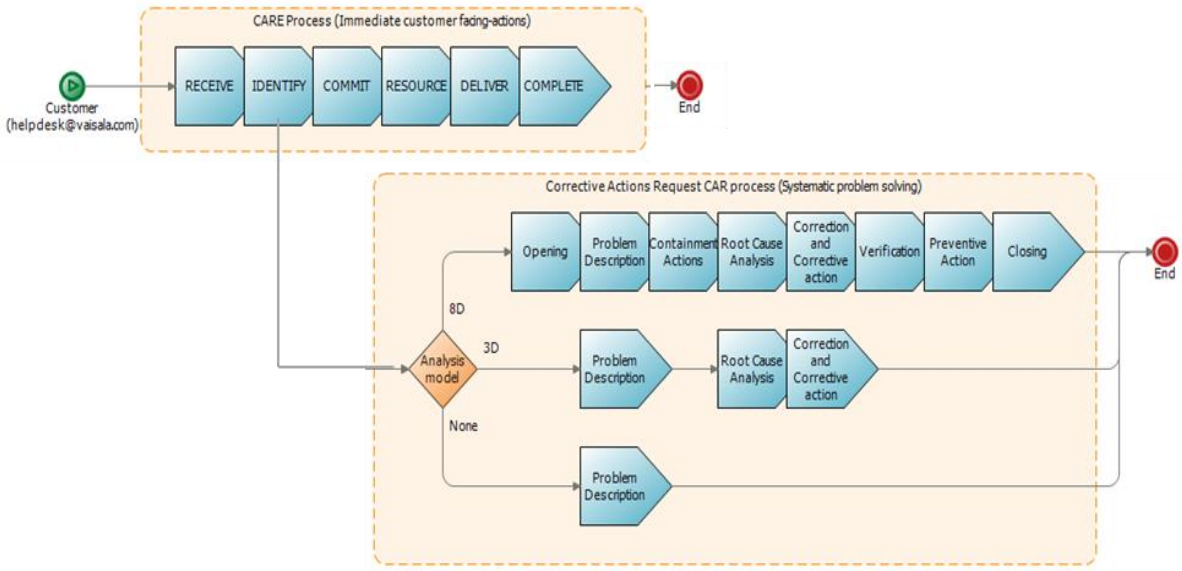


Figure 7 CARE and CAR process (Vaisala 2022b)

The purpose of the customer complaint handling process is to ensure fast resolution to the customer's problem, protect customers from further damage, prevent re-occurrence of the failure and support the continual improvement of products, services and processes.

4.1.1 Types and reasons

Customer Complaint will be set to the Correct Service Request Group based on problem type, nature of issue and solution. Purpose is setting issue to the group which has best competence to serve customer. Most typical reason is out of box failure (OBF). These are forwarded to the OPS support group. OBF is typically a negative experience a user has with new product when first opening the box it comes in and/or installing it at first time, e.g.

- OPS has delivered something that was not ordered
- OPS has not delivered something that was ordered
- OPS has delivered something that does not work

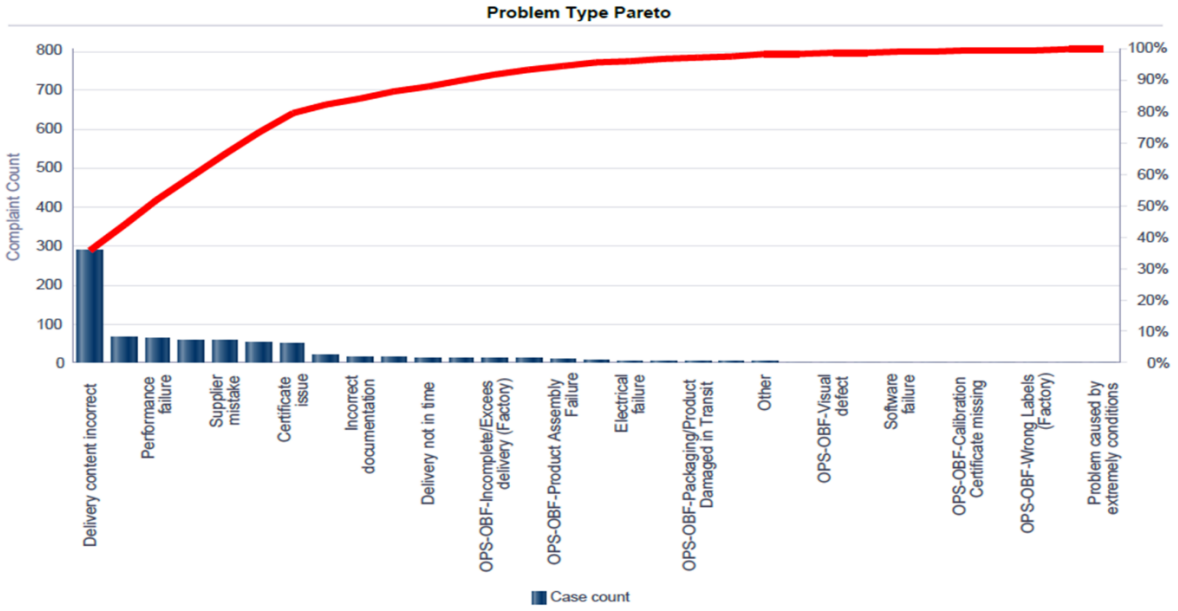


Figure 8 Problem Type Pareto of Customer Complaints (2021-2023)

As can be seen in figure 8 the most common reason for customer complaints is that the delivery content is incorrect. This has been a problem at Vaisala for a long time, and a mistake proof system has been implemented in the instrument factory and the courier packing area, which prevents wrong/deficient orders from being sent to the customer. However, the same solution does not work on the weather factory side and the freight

packing area, where the products are more complex and some of the products are unmarked goods that are under the main product. The products also do not come to the freight packing area in product packages, which makes the work of the packers even more difficult. On the courier side, the process is relatively simple and well controlled by the system, but on the freight packing area, this is difficult to implement due to the complexity and variability of the weather factory products.

In this work, we will focus on OBF errors and the most frequently occurring "delivery content incorrect" subcategory. About 25% of these errors are from weather factory products, which may not sound like a lot, but the delivery quantities of these products in relation to the smaller products from the instrument factory are very small (12% of all deliveries last year). In other words, there is a much higher probability of errors in these products than in any other products. Since these products are very expensive and they are made according to the customers' wishes, the customer expects to receive a high-quality service in addition to a high-quality product. This does not include missing parts or the wrong item in the product box.

4.1.2 Root cause analyisis

Root cause analysis is recognized as an important part of organizational governance. The idea is to identify all of the contributing events that led to the problem. This should lead to a better understanding of the origin of the problem and any intermediate steps where it could possibly be solved. The idea is to eliminate the root cause, but that is not always possible. That's why it's good to identify other intermediate steps that led to the problem. (Okes 2019)

Figure 9 uses the "5 Whys" to explore the cause-and-effect relationships underlying our problem and finding the root cause. It presents the root cause analysis of customer complaints of OBF errors concerning complex weather factory products. These problems

are divided into several small problems, but only the biggest causes are considered in the figure, and other possible intermediate causes are also explained in more detail below, these should not be forgotten when coming up with the solution.

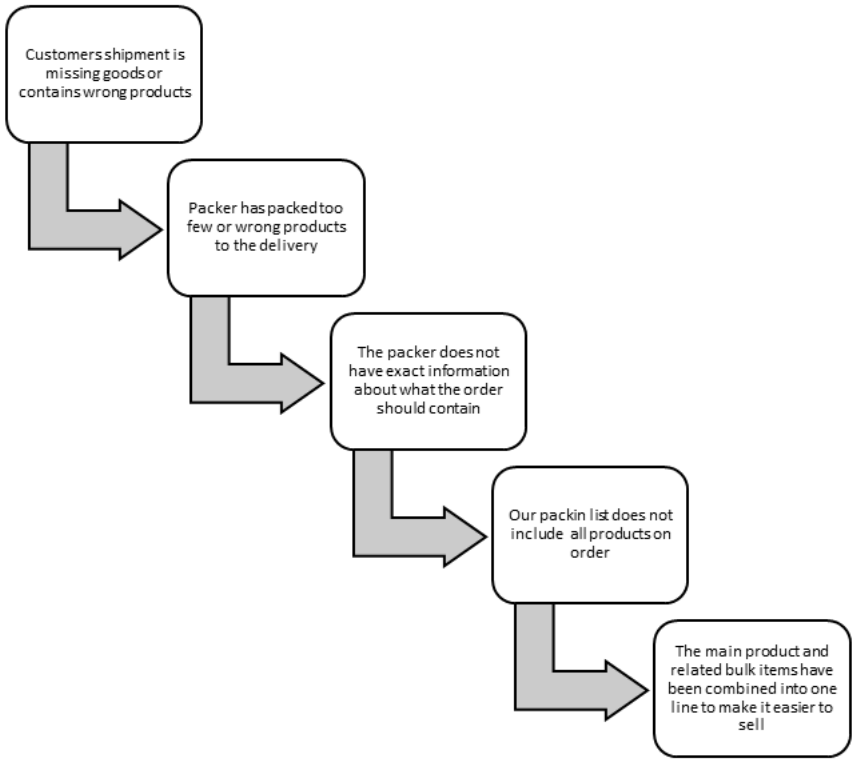


Figure 9 Root cause analysis

If the customer has received the wrong item or something is missing from the order and the error has not occurred in the transport company, the packer has always packed wrong amount of items for the order. This could be due to several different reasons. In the case of complex weather factory products, the packer must rely on the fact that the production will bring all the goods belonging to the order or line correctly and inspected, because the packers do not have the ability to ensure the correctness of the goods. The problem can therefore be caused by the freight packing area mixing orders together, or a product or products that are missing items have gone through the final inspection of production.

The packer is not able to perform the final inspection in the current situation, because not all the goods belonging to the order are separately named on the packing list. Many products also lack a label that would indicate which product it is. Markings are relatively easy to add to products, at least on some level. Getting all items entered on the packing list is a bigger problem. This requires changes to the system and the sales process for these products. It may not be possible to implement because it will affect our sales as it's easier to sell a single title that includes all the goods than many loose ones. This would also require major changes to the productization process, which requires changes to the systems in use. Because of this the problem should be resolved at a later stage or an external tool/system must be introduced to solve the problem.

4.1.3 Loss caused by customer complaints

Customer complaints and the process that follows them always require resources from the company. The receiver must identify the customer and the product in question and give a quick response to the customer to understand the customer's needs and the problem completely. After this, corrective measures are initiated. If the delivery content is incorrect the factory must manufacture the missing products and ship them as quickly as possible. This puts a strain on the work queue of the factory and the packing area and consumes materials that have been acquired according to the current orders. In addition to additional costs, this creates a disadvantage for the number of materials used to other orders, where the situation can already be difficult due to the current component shortage.

The labor and resources used, and the costs of additional transportation reduce the profit made by the company. That's why Vaisala is ready to invest in corrective actions and their testing according to the CAR process. These investments help improve the quality of the delivery process and save resources in the long run. The received customer complaints are mostly due to an incorrect or defective product, which is classified as OBF. This will negatively affect the bonuses of all employees in the operations team. Here we can find a

good motivator for change, if a possible new method to reduce these OBF errors meets resistance among workers.

In addition to sending a customer complaint, some customers may also share their experiences to others. This can harm the company's reputation and, especially with a poorly implemented customer complaint process, lead to the loss of current and potential new customers. (Hansen et al. 1996)

5 Identifying problematic products

Based on the customer complaint data, it was possible to identify the most common weather factory products for which delivery content incorrect complaints were received. For these products, a consistent problem was identified with variable bulk items on orders. After this, all the products and production cells of the weather factory were reviewed in cooperation with process engineers and more products with a similar risk were identified. Finally, from a list of more than 10 products, the manufacturing, final inspection (OQC), transfer, organizing, packaging and shipping processes of each product are reviewed and weaknesses and potential points where corrective measures could be taken are identified. For these products, product managers were also interviewed and inquired about the root causes of the problem and their possible remedies.

This chapter reviews the current state, i.e., why there are problems with these products and what causes the problems. We will also go through mistake proofing as a concept and why it is sought, also the various requirements and limitations to the solution, and of course the possible solutions and their comparison are presented in this section. Data collection is mainly carried out by interviewing experts from different process phases and by monitoring the processes.

5.1 Current situation

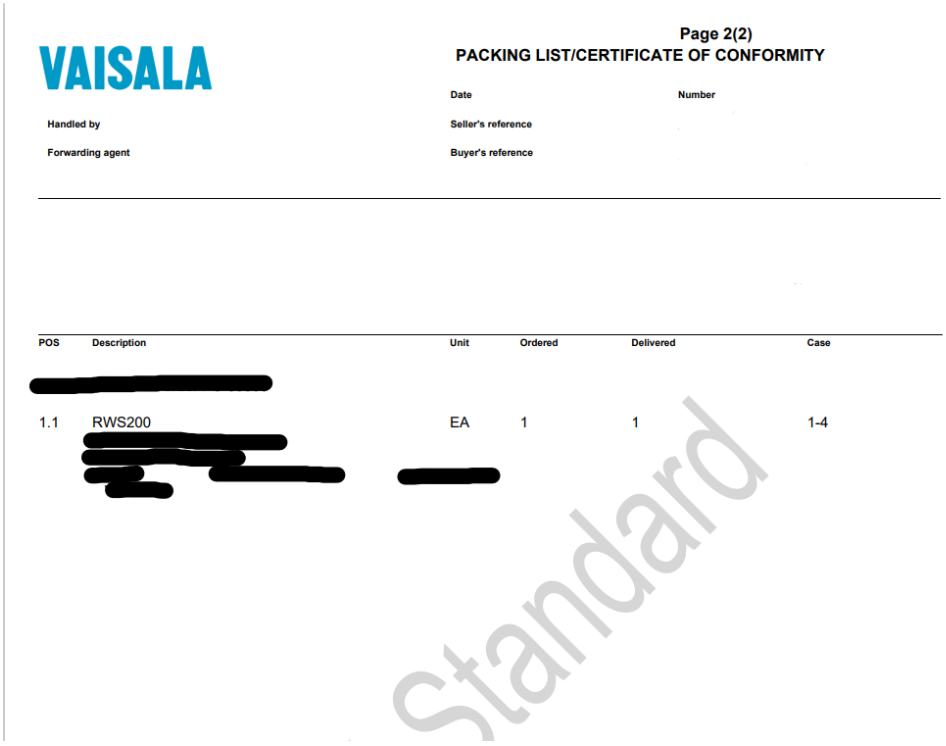
Vaisala’s products and their processes are constantly updated. However, for many products, the effects of decisions made years ago are still visible, e.g., in the problem of identifying loose items that belongs under the main product. In connection with the launch of these products, it has been found that it is easier to sell and manage the product as a whole, than as the main product and loose goods products, which are separated from each other in their

own order lines. This is a better option for sales, purchasing and production planners, because controlling one entity, preparing purchase forecasts for bulk goods and planning production is much easier when all goods are under one heading.

However, the processes of production and freight packing area are affected by these decisions, because in production they have to handle extra items that could go directly from the warehouse to the freight packing organizer, and the organizer and packers in the freight packing area do not recognize the loose products that fall under the main product, because there is no separate entry for them on the order. These factors increase the risks that the customer's order is missing goods or that the order has something that does not belong there. Therefore, ways to solve production and logistics problems must be explored without affecting the sales, forecasting or production planning of these products.

During production, most of Vaisala's products are packed in a product box, which contains not only the main product, but all possible additional parts. The product box has a label with the product name and order number, which helps to identify which order the item belongs to. The more complex weather factory products leave production as different entities. As shown in figure 10, some of the products travel in carts designed for them, with one product set per cart. The Packing list of the same order can be seen in figure 11. This clearly shows how little information the organizer and packer have to work with. That is, if something is missing from the cart, neither of them has a chance to identify it, or if an accident occurs in the freight packing area and something falls from the cart, or the goods are mixed with goods from another order, it is very difficult to know which item belongs to which order.

Figure 10 RWS200 Product cart



VAISALA

Page 2(2)

PACKING LIST/CERTIFICATE OF CONFORMITY

Date Number

Handled by

Seller's reference

Forwarding agent

Buyer's reference

POS	Description	Unit	Ordered	Delivered	Case
[redacted]					
1.1	RWS200 [redacted]	EA	1	1	1-4

Figure 11 RWS200 Packing list

For other products (figure 12), the goods are transferred from production to the organizer in a cart, where the goods of a different order or order line are on different shelves. In these, the amount of goods varies per order and sometimes only the main product is included, and sometimes the main product may include many different cables, mast fasteners or other bulk goods. Here, too, there is a risk that the goods end up on the wrong shelf already in production or they get mixed up in the freight packing area, where the packer just must trust that all the right goods are on the shelf that belongs to them and there is nothing extra.

Figure 12 Product cart

Sometimes these orders also include a mast, which can be seen in the freight packing area as a laminated piece of paper placed with the order by production, which says that the order in question will include a mast and the type of the mast. The packer must remember this and

pick up the mast from the outside warehouse when packing/shipping the order. Even in these orders, no system prevents the order from being sent without a mast. However, this is being changed, and the transfer of masts to their own order lines is one of the many ongoing delivery process development projects.

Some of these problematic products also come in product boxes, but in addition to the product box, various loose cables or boxes may be included. Even if these cables and boxes have labels with the order number on them, they still do not appear on their own line in the order, which is why they can easily be left out of the shipment without anyone noticing they are missing. This is only noticed when extra goods are found lying around or the customer complains about missing goods. Even with these orders, it is impossible for the employees in the freight packaging area to recognize that the order includes extra goods in addition to the main product box, because they do not appear as a separate order line.

Although the processes are not waterproof, they have still been continuously improved. The number of orders received has risen steadily year after year, and at the same time, Vaisala has been able to keep the number of customer complaints at the same and even reduce them. In the production cells, improvements have been made and are constantly being made to the production manufacturing and verification processes by process engineers. At the same time, OQC has increased its inspections of risky products. Logistics processes have also been improved, and the courier packaging areas new packaging process requires barcode scanner verification every time a product is packed. This method of operation cannot be copied on the side of the freight packing area, but there, too, they have moved to shelving the goods according to the order number, waiting for all the products for that order to arrive. This is a big improvement over the old model, where the items were put on a cardboard box/box to wait for the rest of the order to arrive. The old model was completely dependent on the markings made by the organizer, but now you can see directly from the shelf whether all the products are there or not. These and many other small measures have improved the quality of the delivery process, but there is a lack of assurance, especially on the side of the freight packing area.

5.2 Mistake proofing

Mistake proofing is often pursued because of the opportunities it brings. A mistake proof process is often system-driven and therefore enables scaling, and future repairs or changes become significantly easier when the operation depends on the system and not on people. The current strong use of Lean in Vaisala's operations supports the introduction of poka-yoke mechanisms in this project as well. The methods used in poka-yoke enables the use of PDCA (Plan, Do, Check, Act), a problem-solving model and development method used by Vaisala. This enables the utilization of current tools in the solution. The goals of continuous development are also easier to achieve when the integration of the tools currently in use can be easily achieved.

Table 1 Levels of Quality Control that Correspond to Use of Poka-Yoke Devices (Steward & Grout 2001, 44)

Level of quality	Inspection Technique
Defects leave the company	No Inspection
Defects do not leave the company	Judgment Inspection
Decrease defects	Informative Inspection
Defects do not leave process	Self-checks within process
Zero defects	Source inspection

As we can see from table 1, in order to achieve zero defects, we must be able to correct the root cause found earlier in the work. This may turn out to be impossible, and therefore it might be necessary to go one level back and try to prevent the defects from leaving the process. This means self-checks within the process. These self-checks can be carried out during the final inspection of production and/or possibly also at the freight packing area. However, this means that the products must be identifiable in order for the inspection to be carried out. Informative inspection is already in use, so the final solution must be found at one of the two highest levels.

5.2.1 Requirements and limitations

The solution must meet certain criteria. These are determined based on the various requirements and limitations set by Vaisala's processes, systems, goals and operating methods. At the same time and perhaps the most important factor is that the solution must not cause no value-adding activities or repetitive work. This will certainly be studied in connection with the solution alternatives, when comparing the amount of benefit obtained from the solution to the harm caused by it. Since the possible solution is to be implemented this year and its piloting will be completed as soon as possible, priority is given to solutions that can be implemented and tested immediately.

The current ERP system will be replaced by a new one in early 2024, and at the same time many other additional programs such as Planet will be taken out of use, as the new ERP contains similar features. Therefore, the solution cannot be dependent on the current systems if it is not repeatable with the new ERP as well.

Since the processes are designed and integrated into one streamlined whole, it is very difficult to insert an extra intermediate step anywhere without slowing down the whole delivery process or causing a bottleneck. Therefore, the solution must be found by improving

the current processes. Although the skill level of the employees in production and the freight packing area is currently very good, it cannot be relied upon. Employees should be able to do their work in a system-driven manner and they should not be required to have memory-based product knowledge, especially in the freight packaging area. At the same time, this also enables scaling, which supports Vaisala's future growth goals

When developing the solution, its effects on other stakeholders, such as purchasing, production planning, product managers and sales, must be considered. If, for example, goods are separated from the product structure into their own rows, it must be ensured that their forecasts are not affected. Purchasing must be able to predict material needs at least with previous accuracy and, if possible, even with better accuracy than before. The solution must also not lengthen the production planners work queues and their planning must not become more difficult due to increase the amount of goods. Product managers must be able to manage their products and they must be included in the planning if structural changes are to be made to the products.

If, due to process changes, the manufacturing or shipping process of the product becomes longer or shorter, even temporarily, it must be discussed with the product manager and sales, in order to avoid ambiguities and subsequent errors. The solution must not affect the sales volume of the products. If goods are detached from the structure of the main product into their own order rows, it should not complicate sales work or confuse customers when making offers. Sales must also know if structural changes are made to the products, so that they know how to sell the right configuration at the right price and offer the order management specialists a correctly completed order form with all the goods the customer wants.

5.3 Possible solutions and comparison

This section goes through all the potential options that have emerged through studying the processes and interviewing Vaisala employees. Each chapter introduces its own solution and a quick description of what it is and how it works. After this, the pros and cons of the alternative are presented to the reader. At the end, the results are presented, where different solution options are compared with each other using Vaisala's solution requirements as a guideline. Based on this, the most suitable options are selected for the pilot phase, where their functionality is tested in practice.

5.3.1 Manual inspection

The order comes with a paper version of the job list as shown in figure 5, which lists all the components within the structure of the order and outside it. Using this list, all the goods belonging to the order can be identified. The idea would be for the packer or organizer to go through the order's products from the job list manually, one at a time. This is the simplest solution, because it requires nothing more than more work on the packaging side and labels with product names on each item. Some of the products are on the structure of the main product and some separately. The packer/organizer should identify the loose goods from the list and check that they are included. This requires a lot of expertise, at least if the procedure is to be performed quickly.

This solution model does not require any changes or additions to the current systems, and it could be put into use immediately. But at the same time, the solution requires a lot of time and precision from the person performing the inspection. Since some of the items on the job list are attached to the structure of the main product and some are separate, the inspector must be able to identify the items that are separate from the long list. This requires particularly good professionalism, which we cannot demand from the employees of the

freight packing area. At the same time, the error sensitivity of the method also becomes a problem, because going through a long list manually and in a hurry is not the optimal way to make sure that the goods are correct. This idea can be knocked out right away because of its slowness and error sensitivity.

5.3.2 Structural changes to products

A certain order form selection is detached from the product structure as its own order line. In this way, the loose product that comes with the main product can be put in a recognizable form on its own order line, which especially promotes the quality and reliability of the freight packing area operations. However, making a structural change is complicated and requires the cooperation of several different stakeholders. There are also many conditions attached to it, which is why it is not suitable for all products.

Every structural change requires its own project. This project starts at the initiative of the process engineer. The process engineer notices the need for change and evaluates the changes required in the production cell. Then an ECR (engineering change request) is opened for the desired change. Now a person responsible for the changes to the order form must be appointed. If the product to be removed from the structure is not yet an active sales item, it must be made a sales item and the product manager must set a price to this new product.

The ECR goes forward to the Engineering team, which opens an ECO (Engineering Change Order). PCM (Product Change Management) takes it over from it and starts implementing the change. PCM gathers all stakeholders in a meeting where it is ensured that everyone is aware of their own tasks and after that the data changes are sent to Aton and the order form. CPQ (Configure Price Quote) and ERP information must also be updated at the same time. After the changes, the product manager gives sales training on the new structure and its sales.

The change made to the product's structure is permanent and it makes it easier for the employees of the freight packing area to identify the goods and, in addition, it streamlines the entire delivery process, because loose goods sent as such no longer circulates through production but comes directly from inbound to outbound. At the same time, estimating the order size becomes easier, when the order shows individual items in their own order lines. This solution does not require maintenance at all because it is permanent once it is done properly.

However, there are also downsides. It is impossible to implement structural changes for non-configurable products or products for which all product information is not in the configuration code. If the product is tested in production, e.g., the cable included with it cannot be transported directly from inbound to outbound, so it cannot be separated into its own sales item. In the case of larger products, large quantities of loose goods also become a problem, the removal of which from the structure is a long process in itself. In addition to this, selling a large amount of loose goods with the main product can negatively affect the product's sales. An additional challenge comes from predicting the sales volume of the detached loose goods and thereby making it difficult for buyers to buy the right quantities. It must be possible to somehow link the forecast of these products to the sales volumes of certain configurations from the main product.

5.3.3 eFlex Systems

EFlex is a web-based Manufacturing Execution System (MES), which allows to control and track operational operations in production. The system tells the production workers when and what they should do. At the same time, the operational management receives information about what is happening in production and the transmission of information becomes more effective. EFlex Systems advertises themself as a pioneer of digital work instructions. (eFlex Systems 2023)

At Vaisala, eFlex Systems digital work instructions have been implemented on the production side, but only in some of the production cells. The large-scale implementation of this is still in the testing phase and its utilization possibilities are still being investigated. Currently the most used feature is production work instructions which can be modified based on the product and its configuration code. The production operator scans the product's serial number and configuration code, and based on this information, eFlex offers the correct work instructions for production, showing all the work steps and the required components one step at a time.

As shown in figure 13, the same system can also be used in logistics. The work instructions based on the information in the configuration code can be set to show all the loose goods that comes with the main product and, if necessary, even more, if the author of the instructions so wishes. At a later stage, e.g., packaging instructions can be added to the eFlex instructions, which would make training new employees even easier.

The packer/organizer scans the QR code of the product title from a label on the table, which directs the computer to the instruction page for this product. The serial number and the configuration code are scanned there, after which eFlex displays the bulk goods and accessories belonging to the item, one number/letter of the configuration code at a time. The organizer or packer ensures that the item(s) in question are included with the main product, after which they move on to the next item until all items have been reviewed and confirmed.

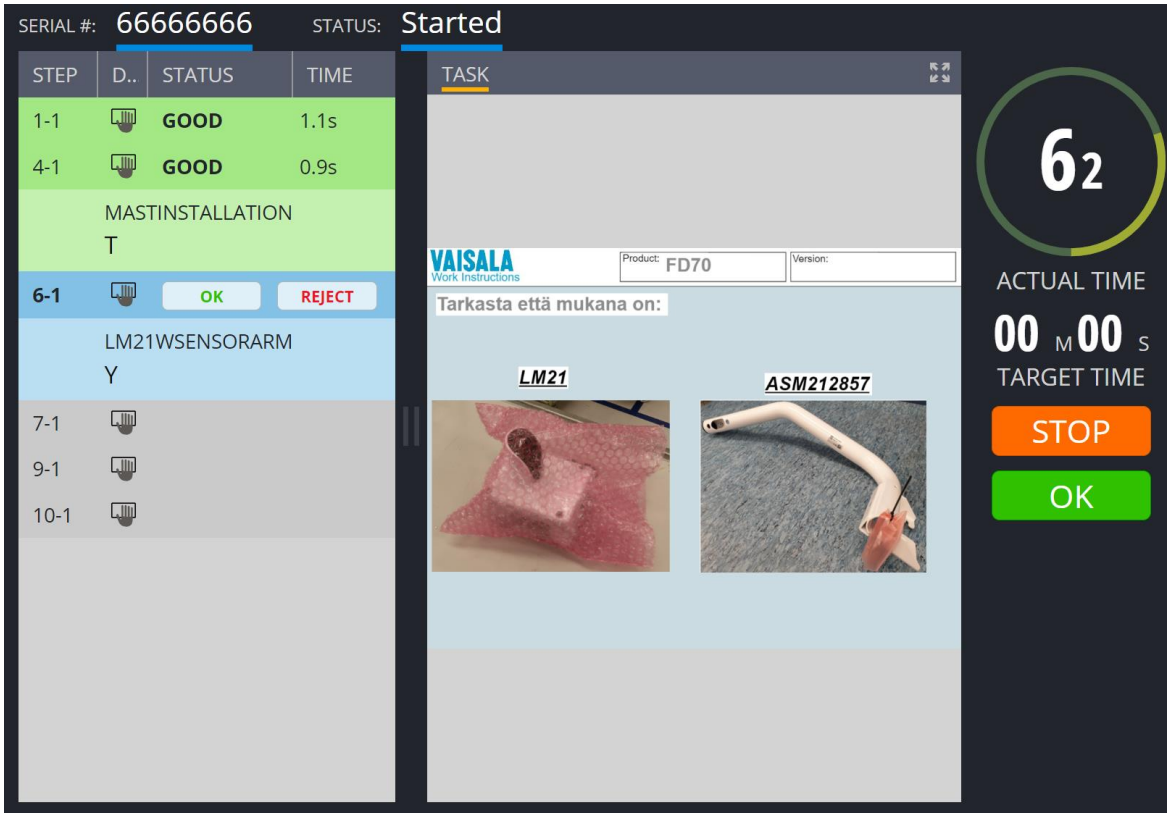


Figure 13 eFlex

EFlex has many good features, such as the possibility of barcode verification and the storage of the serial numbers of inspected products in the system, so that at a later stage it can be verified which products have been inspected. In addition to these features, eFlex is easy to use and its implementation is fast, and it can be done even with small resources. All you need for this is a computer and a barcode scanner, as Vaisala already has a license due to the production work instructions

Making instructions and editing them is easy, someone just has to do it. The possibility of adding pictures is also a big plus. Thanks to this, in the future, in addition to product identification, packaging instructions could also be added to the same instructions. This makes it easier to train new employees with easy and simple instructions to follow. In addition to these, eFlex is web-based and only requires credentials, so anyone who is a Vaisala employee can use it, at the same time restrictions can be set on the credentials, e.g.,

freight packing area employees can only use the work instructions intended for them and cannot modify anything themselves.

No matter how simple and fast the use of the system is, it still creates additional work for the freight packing area. When making the instructions each number and letter option of the product's configuration code must be reviewed, and it must be identified whether the goods will be attached to the structure or loose with the product. This requires a lot of time for some products. In the worst case, there are more than 250 different options, each of which contains several different items, i.e., more than 1000 individual items must be reviewed one at a time.

Some of the products are not configurable or the configuration code does not contain all the product information. For these products, it is impossible to utilize eFlex in its current form, as the product-specific information is based entirely on the configuration code. That is, even if some of the problem products could be checked with this, the problem related to identifying loose products will not be resolved for other products.

EFlex is not integrated into the current ERP system, which is why changes to the instructions and all product structures due to product changes must be made manually in the system. An administrative problem also arises here, i.e., whose responsibility is it to keep eFlex instructions up to date. Due to the lack of integration, performing inspections is also not mandatory and this step can be skipped completely because the current processes do not require this to be performed.

In complex weather factory products, it is common for the customer to ask for the products to be packed in a certain way. These requests are divided between the production and the packing area, depending on which one it concerns. However, this information is not transmitted along with the configuration code to eFlex. Many times, the customer may ask to separate the cables that come with the product, e.g., into their own boxes, already during production. In such a case, the instructions show that the product comes with e.g., one

"accessories box" but in reality, there are two of them and the freight packing area workers must find out why is the product not in accordance with the instructions. This consumes resources from other work and reduces the motivation to use eFlex because its reliability suffers.

5.3.4 VXT

VXT is a custom program created as a side project by Vaisala’s test development team. It was produced between 2021 and 2023. The system is completely built only for the use of SYWLIN cell production and cannot be used as such for anything else. So, it took about two years to make, and it only covers the production needs of three different products. In other words, we won’t get any working program in the freight packing area before the change of the ERP system if we choose this. This also makes piloting very difficult, as piloting the system would only be successful when it is ready, and many things can change in that time.

The system would work in the freight packing area in such a way that the packer scans the QR code of the product name from a label on the table, and then scans the serial number of the product. Based on the product name, the system collects structural data from Excel and based on the serial number, product data from ERP. With this information a figure 14-like list of the loose goods belonging to the line appears on the screen, after which the packer scans all the goods in the order they want, and the program acknowledges the correct ones and gives a return if a wrong product is scanned. When everything has been scanned, the packer can see if everything that was needed was there directly on the screen.

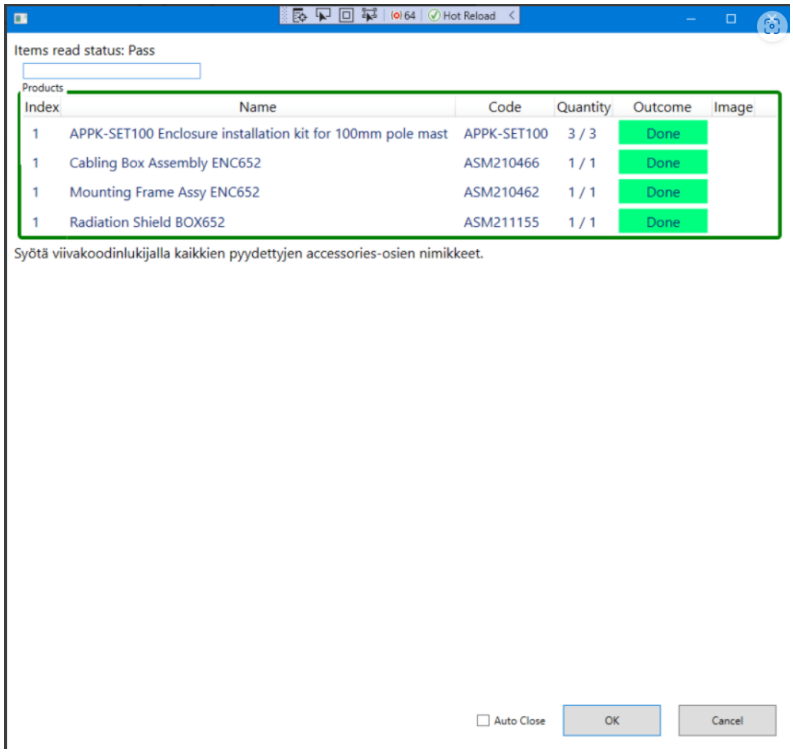


Figure 14 VXT

When completed, VXT is very easy to use, and it could cover all the problem products that have arisen. VXT requires the correct products to be read with a barcode scanner and alerts if the wrong or excess product is scanned. It also does not require product knowledge or a specific working order, as the person performing the inspection can simply read the names of all the products and see how the list on the computer screen reacts to them.

The system would have to be built completely from scratch. This would consume a lot of resources and take even years. A similar solution has been made for one production cell, but this solution is not repeatable because it is built for the manufacturing process of only one product family. In connection with the implementation, administrative problems arise. The program requires accurate and up-to-date product information to function. Making and maintaining these will fall to someone on the logistics side, but who would have the time and know-how? At the same time, the test development team maintains the functionality of the program, and since this is not the team's main task, but an extra project, if the program crashes, fixing it is not necessarily very fast.

Overall VXT is "too good to be true". As a solution it would be perfect, but things outside the system itself, such as its maintenance problems and the slowness and uncertainty of implementation, point strongly against the implementation of this method. Vaisala may want to review the solution options brought by the new ERP system (coming 2024) before committing to such a long project.

5.3.5 Results

In this chapter, the previously mentioned solutions are compared with each other, utilizing the features that Vaisala requires from the solution. The most important features that are desired from a solution are its scope, implementation, and speed. Because if it slows down the delivery process considerably, it is not profitable to use it. The solution is wanted to be used quickly, which is why its implementation must be as easy and fast as possible. In addition to this, its maintenance must not take too much time and resources. The system controllability of the solution also affects its selection, as the ultimate goal is to eliminate the possibility for employees to make mistakes during the process. To compare the solutions, a simple table is used, where each feature required of the solution is evaluated on a scale of 1-5. This table makes it easier to understand the weaknesses and strengths of each solution option.

Table 2 Comparison of solutions

Solution	Implementation	Maintenance	Scope	Easy to use	System driven	Consumption of time	Durability	Total score
Manual inspection	5	5	1	1	1	1	4	18
Structural changes	3	5	1	5	5	4	5	28
eFlex	4	3	4	4	4	4	4	27
VXT	1	2	5	5	5	4	3	25

As shown in Table 2, there is no point in manual inspection. Although its implementation does not require any major measures, its other features do not meet the required criteria. Structural changes are the winner in the total points of the comparison. However, the results in the implementation and especially the scope of this solution are weak. These were two of the three most important features, along with speed. That's why we don't start working on this in this context, but the idea is put forward to process engineers, who can push forward this solution for smaller products, so that they can be removed from the list of problematic products.

EFlex looks like a promising option considering the results. The comparison did not reveal any other noticeable weaknesses than its maintenance. Since the instructions are made manually in eFlex and it is not integrated with current enterprise resource planning systems, the internal changes of the products must also be updated there manually. However, the whole looks good and eFlex is able to meet the three most important categories, because its implementation does not require large changes or workloads, it has the potential to cover even all problem products and its use should not slow down the delivery process at least significantly.

VXT is also a viable option. The biggest problem with this comes in its implementation. Building the VXT system from scratch requires a lot of time and resources, and it cannot be tested in the freight packing area until it is completely ready. Functionality can therefore only be tested in practice when the system is completely ready. After completion, maintenance in particular is expected to cause the most problems. Since the system is self-made and its information is based on numerous excel tables, it is particularly important to keep them up to date. Otherwise, these challenges and risks make a theoretically "perfect" solution sound too risky and challenging to be pushed forward.

Based on these results, the eFlex system is selected for piloting. It can meet all the company requirements at least at a good level. EFlex's piloting is particularly facilitated by the fact that instructions can be created initially for only some of the products, after which it is easy to add instructions to other products if necessary. So, there is no need to immediately commit

to making completely ready-made instructions that cover all products. The possibilities of making structural changes are also explored outside of this work in cooperation with process engineers. Here, however, the main responsibility rests with them. However, the goal is to make the delivery process of smaller products mistake proof by separating loose goods into their own order lines. This way they can be identified in the packing area when the goods arrive and when the order is being packed.

6 Piloting

The main idea of piloting is to do a small-scale implementation to prove the viability of an idea (Arain et al. 2010). In connection with this work, the pilot will be carried out as a short-term test, where a possible way to improve the quality of the delivery process will be tested in practice. If the pilot shows promising results, the methods and procedures will be used on a larger scale. The goal is to assess the feasibility of the changes in processes that are key for the success of the main study.

When we are looking for ways to improve the quality of the delivery process, piloting should emphasize its feasibility. Often the emphasis is wrongly placed on statistics and not on the feasibility of the method. This can lead to misleading results, because in the end we are looking for a workable solution to improve the quality of the work done in the process. Especially due to the limited sample size, the emphasis should be on the functionality of the method in practice instead of its statistical benefits. (Thabane et al. 2010)

This part examines piloting and its functionality in the context of the delivery process quality development project. Objectives are set for the solutions that are the subject of piloting and the most important ones are prioritized. The means used in the piloting are also presented and the reasons why it was done this way are explained. At the end, the results of the piloting are presented, as well as the follow-up measures for the methods in question and in general for improving the quality of Vaisala’s delivery process.

6.1 Objectives

The overall objective is to find a way to improve the quality of the delivery process through piloting. This can't be found just by trying different ways and seeing what felt best based on feeling. To find the right way, clear and measurable goals must be set. From Vaisala's point of view, these goals must be prioritized and thus the comparison of different solutions becomes easier. These goals are listed in table 2, where the functionality of the solution options was studied in theory, but in the pilot, we see how the chosen solution works in practice. This gives a clear picture of its functionality and the potential to improve the quality of the delivery process of products by helping with problems related to their identification. During the pilot, special attention is paid to the solution's implementation, scope and how much time its use consumes. Ease of use of the system also becomes a high priority, as its goal is to facilitate and not complicate the high-quality implementation of the process.

The idea of the pilot is to get clear results about the functionality of the solution, its benefits, and the resulting disadvantages. Based on these, its potential use in the future can be studied. At the same time, the results clarify the overall picture of how the problem should be solved. Here, the key factor is the benefit caused by the means to be piloted in relation to the harm caused by it. However, the results must consider the habits of the employees, i.e., it cannot be assumed that the new method of operation/system will work at full capacity right from the start. Also, whether it is possible to get improvements with small changes that reduce the disadvantages and how these changes affect the functionality of the piloted solution. The sample must also be large enough to avoid false results caused by a too small sample. At the same time, we also see how the employees getting used to the system affects its speed of use. And during the pilot, we also have time to fix possible defects or operating methods.

6.2 Methods

The EFlex pilot was started by creating instructions for a few products and a eFlex system user for the freight packing area workers. After this, in cooperation with the packers and organizers, it was concluded that the packers do not have time to perform extra checks or even computers at the packing points, so the organizer checks the goods arriving at the freight packing area, after which they are put on the shelf to wait for packing. In this way, the packer only has to take the goods from the right shelf, and in this case, it should only contain the right products and the loose components that belong with them.

The piloting began with two products, and a week after starting, the inspection instructions based on the configuration code had already been made for eight different products. The inspection was always carried out when one of the products on the list arrived to the freight packing area organizer. A paper note was brought to the organizer's table with the name of all products to be inspected and a QR code that directs the computer to the correct inspection page. So, the organizer only needs to read the correct QR code and enter the product's configuration code in eFlex in order to view the inspection instructions for that product.

The eFlex pilot lasted a total of 5 weeks. The organizer inspected eight different products, two of which were smaller and six larger weather factory products. The two small products come with an extra cable outside the product box, if the length of the ordered cable exceeds a certain limit. Dozens of these products arrives to the cargo packing house every day and longer cables are very rare, and therefore checking them was considered harmful and time-consuming, and the eFlex pilot was discontinued for the smaller products already after the second week. However, the problems related to the identification of these bulk goods can be solved permanently with structural changes.

6.3 Findings

During the five weeks, we got a good enough sample of the larger products and the challenges related to the system and its use. In the beginning, the ease of using the system was a positive surprise, but then problems started to appear. A lot of problems arose from special packaging methods due to customer requests. Organizer had to go to production to verify these wrong looking orders several times. These seemingly incorrect orders were due to special requests from the customer that are not reflected in the configuration code. Because of this, the instructions showed incorrect information and the Organizer thought that the product that arrived at the freight packing area contained an incorrect amount of loose goods.

Another problem was that eFlex is not integrated into the current systems, and due to the weekly rotation of the organizer, the organizer had to be reminded every time at the beginning of the new week that he should carry out inspections for these specific products. Still, many products were not inspected, especially smaller products, because it was considered inconvenient due to their large quantities. Due to this, the inspection of the smaller products was stopped after two weeks. A system integrated into the process would force an inspection to be carried out at a certain stage of the work. In this way, we would be able to check all the products before sending them to the customer, improving the quality of the delivery process.

EFlex worked exactly as it was supposed to, but the solution model did not meet the goals set for it and did not please the employees of the freight packaging area. The Final Inspection carried out in the freight packing area was considered too cumbersome and laborious, and it did not eliminate the possibility of the freight packing area making internal errors. So, the benefit from the eFlex system was felt to be minimal. At the same time, its manual nature and thereby enabling errors to pass through did not convince its functionality at this stage of the process.

After the pilot, it was clear that eFlex is indeed better suited to its intended use, i.e., creating work instructions, and the same model cannot be used successfully for the final inspection. Although a direct solution to the problem related to product identification was not found, much was gained from the piloting and the feedback. Based on the results of the pilot, it is easier to assess what kind of final assurance is suitable for the freight packing area and what measures this requires from production in order to mistake proof Vaisala's delivery process.

6.4 Follow-up measures

Thanks to the eFlex pilot, it was noticed that a separate work instruction is not the right way to mistake proof Vaisala's delivery process. The solution must be fully integrated into the delivery process, and it must not hinder the flow of the process. This requires changes to the systems in use and operating methods at the factory and in the freight packing area. One sure way to mistake proof the product delivery process is to have all products in product boxes and scan these product boxes into the system during packaging. This ensures that the goods are correct, and at the same time, the verification of the presence of the correct loose goods is transferred to the production side, which has the know-how and tools to check that all the loose goods go into the product boxes. At the same time, the current various product-specific carts, which are always too many or too few, can be phased out and the transport methods between the factory and logistics can be unified. Especially for larger products, this requires changes to the production processes, because instead of carts, the products should be packed in marked product boxes already during production.

It would be good to try this operating model in the freight packing area for smaller weather factory products. These products are already mostly in product boxes, so the only major changes would have to be made on the packaging side. The packaging process should therefore be changed in such a way that for the product to be packed in the system, the packer must scan the barcode found in the product box. This way we can make sure that the right products are in the right boxes, and nothing extra gets lost there. If the new operating model

is found to work for smaller products, it is also easy to justify the packaging of larger products in product boxes already in production, and the operating model based on reading the barcodes during packing is therefore easier to extend to the delivery process of larger products as well. At the same time, it avoids making major changes on the production side before the new operating model has been tried in practice with smaller products on the side of the freight packing area.

Just the mistake proofing of the delivery process of smaller packaged products already has a big impact on the measurement results in use. For these, the volumes are high and therefore the OBF quantities are the largest in the weather factory. In 2022, the "delivery content incorrect" errors of the weather factory's volume products covered 25% of all customer complaints received concerning the weather factory products, so even doing only this change will have a big impact on Vaisala's results.

The current system in use supports packaging based on scanning the barcodes, but it does not require it. Without supervision, this leads to the fact that especially more experienced packers may skip this step entirely by copying the product information directly from the order. To prevent this, the system in use should require information from each product which is easier to read with a barcode scanner than copying from the order information while packing. Currently, the freight packaging area is not ready to start implementing packaging based on scanning barcodes from product boxes. Existing packing stations must first be equipped with computers, tablets or newer, more sophisticated barcode readers that automatically update the data in the ERP system.

Since the ERP system in use is about to change soon, it is not worth changing the processes too much now. The current steps of the delivery process will need some changes so that it can work at full capacity with the new system. At the same time, the new ERP system is expected to bring new opportunities to improve the delivery process. In the beginning, only the basic version is used, so that the whole operation does not crash. But with the help of add-ons available for it, it may be possible to demand a final inspection based on scanning

the barcodes when packing the products. However, this will only become clear once the new system has been put into use and the possibilities of its expansion are being investigated.

Although at the moment the focus may no longer be on finding a single working solution, but rather on improving the processes of both the factory and the freight packaging area by various means, it is still good to be aware of the means by which mistake proofing can be implemented. It is easier to steer the requirements of the new system and process changes in the right direction when the goal and the requirements for the system and the process required to achieve it are already known.

7 Conclusions

The main objective was to find out what are the correctable causes of incorrect shipments sent to customers and explore ways to mistake proof the processes of these products. In support of this main objective, three sub research questions were set, which made it easier to move towards the larger goal. In these sub research questions, we wanted to find out the root cause of the problem and its possible correction, what other challenges affects the solution, and what are the possible solutions.

Problems related to product identification on the side of the freight packing area were found to make it difficult for the packers to be aware of what they should pack for the orders. The root cause of this problem was identified, and its direct correction is not possible without causing problems in other areas of operation. There is also other challenges in solving the problem, such as the fact that the processes, especially on the production side, are very complex, therefore making changes there is very difficult. In addition to this, the processes has been optimized according to the principles of lean and modifying these sub processes can slow down the entire delivery process or create a bottleneck in one of the stages of the process.

The cost issues of the solution should also be considered. The most important question is, is the benefit obtained from the additional work done greater than the costs caused by it? This should be thought about especially if the freight packing area packers start scanning barcodes on all the products that arrive or are packed there, or if larger products start being packed in product boxes during production. Because it is cheaper to carry out the packaging at the packaging area due to the salary level of the employees. Changing the main ERP system at the turn of the year also poses its own challenges for making changes. But the new system also opens opportunities, the impact of which is very difficult to assess in advance.

Despite all these challenges, we collected possible solution alternatives to be piloted, the comparison of which emphasized especially the ease of implementation, the scope of the solution and the additional work it causes. Based on these and other set criteria, eFlex systems the system intended for production work instructions was selected for piloting. This system was used when the freight packaging area organizer received goods, and although it was finally determined that this is not the right way to solve the existing problem, potential other ways to improve the quality of the delivery process were found thanks to the results obtained from this pilot.

In the pilot, it was noticed how the manual and non-mandatory final inspection is often either not done or workers are taking shortcuts with its use. Also, constant changes and special wishes with products makes a non-integrated system not completely reliable. Because of this, we noticed that the only effective way to ensure the correctness of the products to be packed is that the system requires the packer to read the product information, e.g., from the barcode by scanning during packaging. This way we can eliminate mistakes made during the packaging phase of the delivery process. To ensure that customers do not receive any wrong or missing goods in the future, the production processes must also be improved. This is the responsibility of the skilled process engineers who have already started to implement the eFlex systems work instructions into production.

If we want direct and visible results, we should focus on the mistake proofing of the delivery process for smaller products, after which it will be easier to expand it to include larger products as well. Especially if the longer-term results obtained from this are promising. Based on the results of this work, we are going to investigate packaging based on scanning and its functionality for various weather factory products. This time, however, we are focusing on the possibilities brought by the new enterprise resource planning system. It is also a good idea to set structural requirements for new products in such a way that all goods outside of the main product can be easily identified either on their own order line or all goods can be placed in a marked product box in order to avoid problems related to identification in the future.

8 Summary

Years of growth and continuous improvement goals set by Lean directed Vaisala's eyes towards improving current processes. It was noticed that there was room for improvement in the delivery process, based on the customer complaints received. As a result, Vaisala decided to fund this diploma thesis project, which aims to investigate ways to improve the quality of the current delivery process. The research started in February 2023 by studying the stages and challenges of delivery processes relevant to the work at a general level and after that the same issues were reviewed in the target company. After reviewing the current state of the process, it was time to figure out how to execute this project.

In the next phase of the work, customer complaints and the process they went through were investigated. Based on customer complaints, it was possible to identify the causes that led to the most common problem and the steps in the delivery process where errors occur. The harm caused by customer complaints were also reviewed. Once the problem and the causes that led to it were clear, it was time to find out which products are affected by these challenges. More than 10 products with a similar risk were identified, after which the current state of problems related to the identification of these products was reviewed.

After identifying the problem products and the current state of their delivery process, it was time to focus on the solution and the requirements and limitations set by the company's operating environment. The possible solution options were reviewed, their properties were evaluated, and different options were compared with each other. Based on this, the eFlex system was chosen for the pilot of the next work phase, thanks to its easy expandability and the ability to meet all the goals set by the company.

In the initial phase of the pilot, the objectives were set and the methods to be used were identified, i.e., how the pilot was implemented and what it wanted to achieve. After the pilot

ended its results were presented and based on these it was concluded that eFlex is more suitable for the production environment than as an additional help for the freight packing area organizer. Based on the pilot, however, it was possible to identify the phases of the delivery process where possible mistake proofing could be performed and what measures it requires. In the follow-up measures, the emphasis of the future solution is on the use of an integrated system and barcode readers.

Based on the work, we are going to change the layout of the packaging points so that packers have the possibility to scan the products during packaging. This makes it possible to immediately change the packaging process of smaller products packed in product boxes to a system-driven one. With this change, we can immediately eliminate over 5% of all Vaisala OBFs. For larger products that do not come to the freight packing area in a product package, we must rely on the factory for the time being, but in the future the productization of loose components would enable an inspection based on scanning of each loose component during packaging. In this way, it could be possible to eliminate all "delivery content incorrect" errors caused by the freight packing area in the future. At the same time, ensuring that extra loose components and missing ones due to production are noticed at the latest in the packaging phase, also reducing customer complaints caused by the weather factory.

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