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Developing the monitoring of the critical part deliveries at ŠKODA AUTO a.s.

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Thesis abstract

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The thesis was commissioned by ŠKODA AUTO a.s., a traditional Czech car manufacturer. The practical work was performed under a department called PLD/1 (Production, Logistics, Disposition). The department monitors incoming part deliveries if they are found to be critical because of the low inventory level.

The need to improve the work of the PLD/1 department had arisen, as monitoring with current methods required plenty of phone calls and emails thus tying up labor capacity. Therefore, an electronic platform was needed, that would provide the necessary information without special requests.

The objective of the thesis was to create a vision of the platform and to consider the steps needed to accomplish it. A two-day observational study was carried out in the PLD/1 department, during which employees wrote down all calls and emails as well as their reasons and recipients. The research revealed that communication with forwarders and truck drivers was the most important issue to be developed, as the delivery stages during transportation were often unknown.

The thesis resulted in a vision of an electronic order tracking system, which was estimated to reduce the number of calls and emails by 53 percent. The different stages of transportation will be stored in the system with a mobile application by reading a QR code printed on the delivery documents, and some other information would be transferred automatically from other applications. The thesis also provides a list of the measures needed to implement the vision.

The objective was fulfilled because both the vision and the steps are found in the thesis. The criteria for success determined by the commissioner was that the vision should be well argued and based on reliable research and comprehensive data analysis, and also these requirements were met.

Keywords: delivery tracking, critical part, digitalization, production management, supply chain management, logistics, Škoda, action research,

SEINÄJOEN AMMATTIKORKEAKOULU

Opinnäytetyön tiivistelmä

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Opinnäytetyön toimeksiantajana toimi ŠKODA AUTO a.s., joka on perinteikäs tšekkiläinen autonvalmistaja. Käytännön työ suoritettiin yrityksessä sellaisella osastolla, josta käytetään lyhennettä PLD/1 (Production, Logistics, Disposition). Osasto valvoo kriittisten osatoimitusten saapumista ja pyrkii turvaamaan keskeytymättömän tuotannon. Toimitukset nimetään kriittisiksi, jos kyseisten osien varastosaldot laskevat tietyn hälytysrajan alapuolelle.

PLD/1 osastolla oli todettu, että toimitusten seurannan suorittaminen nykyisin järjestelmin edellyttää usein informaation kysymistä puhelimitse tai sähköpostilla, mihin kuluu runsaasti työaikaa. Käytössä oli muutamia sähköisiä järjestelmiä, mutta läheskään kaikki tarvittava tieto ei ollut niiden kautta saatavilla. Oli syntynyt tarve järjestelmälle, josta kaikki informaatio löytyisi yhdellä kertaa.

Opinnäytetyön tavoitteeksi asetettiin tällaisen järjestelmän ideoiminen, sekä sen käyttöönottoon tarvittavien lisävaiheiden pohtiminen. Suunnittelun tueksi PLD/1 osastolla suoritettiin kaksi päivää kestänyt havainnointitutkimus, jossa työntekijät kirjasivat ylös kaikki yhteydenottotilanteet, niiden syyt sekä vastaanottajat. Tutkimus osoitti, että kommunikointi kuljetusliikkeiden kanssa on olennaisin kehityskohde, sillä lähetysten vaiheet toimittajalta lähdön jälkeen olivat usein pimennossa.

Työn tuloksena syntyi visio sähköisestä lähetystenseurantajärjestelmästä, jonka arvioitiin vähentävän puheluiden ja sähköpostien määrää 53 prosenttia. Siinä kuljetuksen vaiheet tallennettaisiin lähetysdokumentteihin tulostuvan QR-koodin avulla mobiilisovelluksen kautta, ja muita tietoja siirtyisi automaattisesti toisista järjestelmistä. Työ listaa myös tulevat vaiheet, joita vision käyttöönotto edellyttää.

Tavoite täyttyi, sillä sekä visio, että sen toteuttamiseen tarvittavat vaiheet löytyvät opinnäytetyöstä. Työn onnistumisen kriteereiksi toimeksiantaja nimesi, että vision tulee olla hyvin perusteltu, pohjautuen luotettavaan tutkimukseen ja siitä saatavan datan kattavaan analysointiin, ja työ toteuttaa myös nämä vaatimukset.

Avainsanat: lähetysten seuranta, kriittinen osa, digitalisaatio, tuotannonohjaus, toimitusketjun hallinta, logistiikka, Škoda, toimintatutkimus

TABLE OF CONTENTS

Figures and tables

Terms and abbreviations

PLD/1	The name of the department that commissioned the thesis, an acronym from Production, Logistics, and Disposition.
Forwarder	A freight forwarder, a forwarding agent – a person or a company providing transport services.
Supplier	A vendor, a seller - a person or a company providing the parts or materials needed in production.
Cross-docking center	A special warehouse where shipments from several senders to several recipients are rearranged.
Inventory level	A number of stored products.
Layout	Refers to how machines, workstations, passages, warehouses, etc. are positioned in relation to each other.
Supply chain	A network of companies and operations on the product's way from raw material to the final customer.
Cycle time	The time from the completion of one product to the completion of the next product.
Lead time	The time from the beginning of the process to the completion.
Operating time	The time when the machine is running, i.e. carrying out work.
Production coverage time	The period how long the inventory has parts for production.
Setup time	The time it takes to change machine settings.

1 INTRODUCTION

For clarity, this paper begins with a presentation of the company that commissioned the thesis which can be found in chapter 1.1 Thus, it is possible to progress coherently by presenting the department under which the work was performed in chapter 1.2, and thereby provide sufficient background information in chapter 1.3 to define the research problem and the objective of the thesis.

The work proceeds in the following chapters so that principles of Production Management are presented in chapter 2, and general knowledge about Supply Chain Management is given in chapter 3, to make it easier for the reader to understand the framework of the thesis. Since the work includes research, the theory on the research methods is also discussed in chapter 4. Description of the present conditions of operations is given in chapter 5 and information about the research work will follow in chapter 6. The data generated by the research is analyzed and the proposed solutions mentioned in chapter 7. Finally, chapter 8 summarizes the content of the thesis and assesses the success of the project.

1.1 ŠKODA AUTO a.s.

ŠKODA AUTO a.s. is a traditional car manufacturer, with headquarters and automobile development department in Mladá Boleslav, Czech Republic. In addition to the Mladá Boleslav factory, the company operates production plants also in Kvasiny and Vrchlabí. (About Škoda 2019.) The company develops, produces and sales ŠKODA vehicles, components, genuine parts, and accessories. (ŠKODA AUTO a.s. 2018 a, 11.)

The story of the company began in the year 1895 when Václav Laurin and Václav Klement built together a bicycle called Slavia and set up a firm. After only ten years, the first vehicle was completed by the Mladá Boleslav plant in 1905. (About Škoda 2019.) In 1924 the company merged with ŠKODA Works, and later it has become a part of Volkswagen Group: at first only partially (a 30% share in 1991), but since 2000 completely (ŠKODA AUTO a.s. 2018 b; Majer 2019).

Many things have changed and evolved over the years, and nowadays the company employs more than 31 600 people in the Czech Republic and in the year 2017 the company produced more than 858 000 vehicles.. Outside of the Czech Republic, ŠKODA-branded cars are also manufactured in China, Russia, India, Slovakia, Ukraine, and Algeria. The worldwide production since 1905 surpassed 20 million vehicles in September 2017, which is a kind of testimony of the company's long history. (ŠKODA AUTO a.s. 2018 a, 11, 34, 38.)

1.2 Department information

Organization of ŠKODA AUTO a.s. is divided into seven main departments, which are Board Chairman, Finance and IT, Sales and Marketing, Production and Logistics, Technical Development, Human Resources Management, and Purchasing. They are further divided into several smaller parts and under the Production and Logistics, there is a unit called PLD. The PLD is an acronym from the words Production, Logistics, and Disposition. The duty of the PLD department is to ensure the supply of outsourced parts for the production to the factories in the Czech Republic and the shipments to the plants abroad. (ŠKODA AUTO a.s., [Ref. 10 January 2019].)

The PLD department consists of eight sub-departments and the thesis is made under the first of them, which will be hereinafter referred to as the PLD/1 department. The PLD/1 department secures that parts are in the warehouses of ŠKODA AUTO a.s. when needed. The parts may be supplied from subcontractors or other Volkswagen Group divisions and used in production either in Czech Republic or other countries. The latter refers to the countries mentioned earlier, where ŠKODA-branded cars are produced by licensed manufacturers. The PLD/1 department does not actually place the original orders or organize shipments abroad, but monitors the arrival of the deliveries if they are found to be critical. (Raz 2019.) The criteria for designating parts as critical are presented in chapter 5.2.

1.3 Research problem, the objective, and the applied research methods

At present, a lot of time is used for phone calls and emails to get information about incoming deliveries. It is somewhat wasted time since some of the questions are just routine checks and the data could also be provided in other ways. Therefore, a need had arisen to improve the work of the PLD/1 department by increasing the use of digital services. There are, naturally, some electronic systems already in use, but not all the necessary information is available in digital form.

Based on the need for improvement, one issue has been selected for the subject of this thesis, and it can be presented as the main research problem as follows: *How to reduce the need to contact someone to get information*? The main problem can be divided into two sub-problems, which are *How to reduce the number of calls?* and *How to reduce the number of emails?*.

The long-term goal is that all the information that is routinely needed to monitor the critical deliveries can be found in electronic platforms without any special requests. The objective of the thesis is to create a vision of such a platform and to consider the steps needed to accomplish it. The vision aims to be well argued and based on reliable research and comprehensive data analysis.

The heart of this thesis is the action research carried out at the PLD/1 department. Its purpose was to find out how often calls or emails are needed, who are contacted and why. Thus, the research formed the basis for the vision. The study is empirical, as it is based on real experiences and observations that occur in the daily work of the department. Due to the small size of the population, it was decided to aim for a total sampling. The research determines the situation only at a single point of time and does not follow the development of it, so the time perspective is cross-sectional. the work included both quantitative and qualitative approach, as at first numerical data was collected from a larger population and then the causal connections behind the cases were investigated through individual interviews.

2 PRODUCTION MANAGEMENT

If *production* is defined as a process to create products or services from different input resources, *production management* can be said to be an activity, where all this is done in a controlled manner under the policies of an organization. The resources include employees, materials, machines, capital, and information. Production management is that specific part of the organization, which is responsible for transforming inputs into output with the required quality level. In conclusion, it can be said that production management is an interrelated set of management activities designed to produce a particular product or service. (Anil Kumar & Suresh 2007, 1-2.)

The next chapter explains the goals of the production management and it is followed by four topics relevant to the thesis. The issues are production forms, just-in-time philosophy, production disruptions, and the defining of a critical item.

2.1 Goals of the production management

The purpose of production management is to match sales and the production resources so that the company's goals can be achieved. In addition to the efficient use of assets, it is important to send and receive information about the statuses and delivery times of orders with the company's customers and suppliers. (Kivistö 2015, 3.1.1.) Achieving these goals requires appropriate technical organization of production and a suitable production management system (Häkkinen 2003, 17). The production management system is primarily an information system providing data for making the right management activities possible (Kivistö 2015, 3.1.1).

High capacity utilization, minimizing the current assets, and delivery reliability are usually named as the most important goals of production management (Figure 1). The emphasis is not always in the middle, but it depends on how the different targets are weighted. In general, all the objectives are not perfectly achievable at the same time. (Häkkinen 2003, 16-17.)

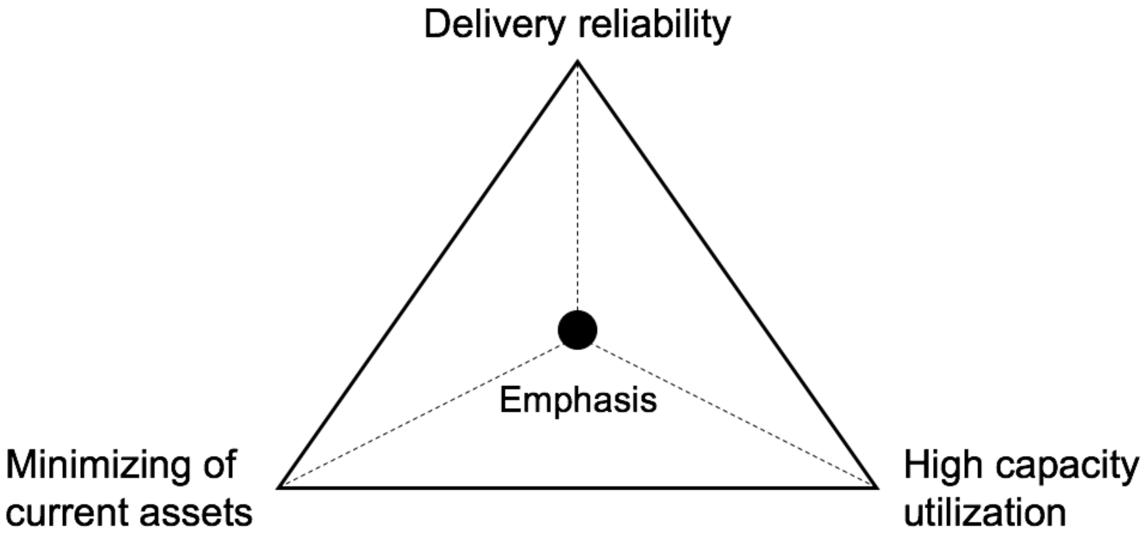

Figure 1 Goals of the production management (adapted from Häkkinen 2003, 16).

Different departments of the company may have different views on the importance of the objectives. For example, a marketing department may consider delivery reliability as the most important, the main goal of manufacturing may be high capacity utilization, and people responsible for the economy would like to achieve low current assets. It is necessary to have a common view on this issue to operate the company efficiently. (Haverila, Uusi-Rauva, Kouri & Miettinen 2009, 404.)

Capacity refers to the maximum performance or efficiency of a production unit within a given time. It is presented in different units depending on the properties of the object being measured. For example, the total capacity of a car factory may be 3000 vehicles per day, whereas the capacity of human labor in some particular stage of the assembly line could be 100 hours per week. The capacity should be utilized as well as possible, to ensure that the capital used to achieve the capacity would be productive. Making settings when changing a batch consumes operating time, so manufacturing in longer series usually allows for a higher utilization rate of the machines. (Haverila et al. 2009, 399, 402, 403.)

Current assets are materials and supplies as well as semi-finished and finished products. A common determinant for them is that the items are intended for an assignment or consumption as a part of the company's business. Thus, the current assets differ from fixed assets, which are available for the company for a longer time. (Statistics Finland, [Ref. 25 January 2019].) The current assets bind a lot of capital, so manufacturing and material activities should be managed in such a way that the number of the current assets can be reduced. It is usually done by minimizing inventories. (Haverila et al. 2009, 402-403.)

If a company has good **delivery reliability**, it means that they are taking good care of the agreed delivery times. It also includes a high ability to produce and deliver items according to the customer's needs. The customer must be able to trust that if the work is promised to be completed in a week, it will be ready within a week, and it has such properties and quality as agreed. Usually, large inventories are needed for good delivery reliability. (Haverila et al. 2009, 402.)

As the reader can easily detect, the above-described objectives are somewhat conflicting. For example, manufacturing in large batches brings on big inventories whereas achieving low current assets requires them to be reduced. According to Haverila et al. (2009, 404), reducing lead times is an effective way to reach these contradictory goals. Lead time is a period from the placement of the order to delivering goods to the customer (total lead time), or from the start of production to the completion of the finished product (manufacturing lead time) (Koski 2015, 12). Short lead times reduce delivery times without any need for large inventories. If the time is, furthermore, removed from machine setup times, it is possible to utilize the capacity of machines better. (Haverila et al. 2009, 402.)

Anil Kumar & Suresh (2007, 7-8) present the goals of production management differently, setting the starting point to the characteristics of the product. They divide the objectives into four parts as follows:

1. **Right quality** – Quality should be based on the needs of the customer. It is not always necessary to produce the best achievable quality, only the grade for which the customer is willing to pay.

2. **Right quantity** – Overproduction consumes the capital and underproduction leads to problems with product deliveries, so production volumes and inventory levels must be appropriate.

3. **Right time** – Timeliness of deliveries is one of the most important indicators of the efficiency of a production unit. If there is a delay with shipments, a

customer can claim for a refund, or decides to order the goods from another company the next time.

4. **Right manufacturing cost** – Manufacturing costs are attempted to be kept within the limits defined before the start of production. A customer is not supposed to pay for the supplier's mistakes, so in case of an error the profitability of a product decreases. (Anil Kumar & Suresh 2007, 7-8.)

2.2 Different forms of production

Production systems can be classified according to the production volumes and variability of a single product. Anil Kumar & Suresh (2007, 4) have divided the processes into four basic types, which are continuous, mass, batch, and job-shop production. Figure 2 shows an illustrative diagram of the classification.

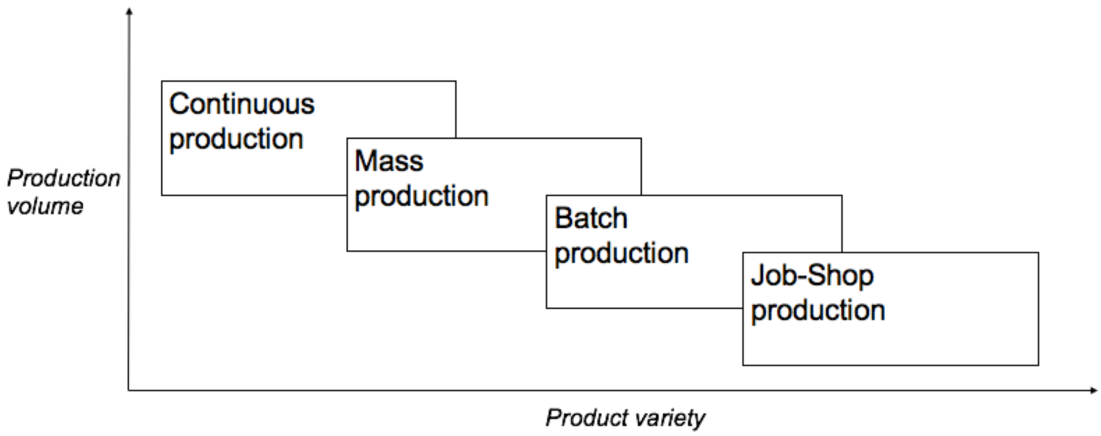

Figure 2 Classification of production systems (adapted from Anil Kumar & Suresh 2007, 4).

Job-shop production is characterized by the project-type production of individual items or small quantities of products considering the personal requirements of the customer. Employees have general-purpose tools and machines in use and they are highly skilled to do even complicated jobs. There must be a large stock of parts and raw materials because a customer can order anything. Manufacturing of any product usually requires detailed designing and planning. This production system enables creative methods and innovative ideas, but the costs rise to a high level, as large spaces are needed for work and storage and production planning is complicated. (Anil Kumar & Suresh 2007, 4-5.)

Batch production means that a limited number of products are made at regular intervals. For a single batch, one may need to make significant changes to the machine settings. On the other hand, the operating time of machines can be high, because it is possible to work with the same settings through the whole batch. Costs of an individual product are lower than in job-shop production, but material handling is more complicated. The need for material is irregular, but when consumption begins, large amounts of material are often needed. (Anil Kumar & Suresh 2007, 5-6.)

Mass production is a process, in which the product manufacturing or assembly of parts proceeds an unbroken, continuous path. In every stage, there are machines and tools specifically planned for the particular job thus their capacity can be utilized efficiently. The volume of production may be high, but items characteristics must be standardized. Short cycle times are achievable, which means that finished products will be completed at short intervals. Separate working stages should be balanced with each other because the slowest stage determines the cycle time of the whole production. Mass production requires accurate layout planning, the precise design of the tools, and large investments. The breakdown of one machine usually stops the entire production line. (Anil Kumar & Suresh 2007, 6.)

Continuous production is common in food production as well as the chemical and petrochemical industry (Kivistö 2015, 3.1.3). Usually, there is no flexibility for the various characteristics of products in the process and the sequence of different operations is precisely defined beforehand. Material handling is fully automated, which decreases the need for human labor and lowers product costs. Creating new production lines, or making changes to existing ones, requires costly investments. (Anil Kumar & Suresh 2007, 6-7.)

The above-mentioned grouping is based on the characteristics of the manufacturing *process*, but it is also possible to distinguish the production forms according to the manufacturing *initiative* or features of the product. The manufacturing initiative can be obtained by the order of the customer or by changes in the inventory level. If production starts only after the order is received, it is **customer-driven production** using the term “MTO” (make to order). In turn, **warehouse-driven production** (MTS, make to stock) is an activity where production is started when the inventory level of finished products falls below a certain threshold. (Haverila et al. 2009, 353-354.)

Depending on the properties of the product, custom and standard production can be differentiated. In **custom production**, the final features of the product are determined by the customer’s wishes and the articles are unique. If the basic data of the product remains the same for long periods, it is **standard production**. (Haverila et al. 2009, 353.)

2.3 Just-in-time management philosophy

The name “Just-in-time” (JIT) describes the basic principle of philosophy that nothing is produced or acquired before the need, but at the right time. The method is originally developed in Japan in the 1970s by Mr. Taiichi Ohno, after which it has spread widely in the industry around the world. The method aims to reduce the extra unproductive activity (“waste”), reveal problems, and eliminate bottlenecks. (Khanna 2015, 440-441.) JIT production is characterized by high quality, high productivity, low tied-up capital and short lead times (Haverila et al. 2009, 428).

According to Haverila et al. (2009, 428), JIT has proved to be better than other production management methods. But why? And how can these good qualities (mentioned in the previous paragraph) be achieved? The subject has been discussed with very extensively in the literature, so means and instructions are well available.

The different forms of waste are presented in the following chapter, after which the special features of the philosophy are discussed in two chapters. These three parts together answer the questions above.

2.3.1 Seven wastes

A journey to the world of JIT is advisable to start by looking at waste eliminating, which is perhaps the most widely known thing about the philosophy. Taiichi Ohno sorted waste (according to Khanna 2015, 442 and Hill 2018, 10-11) into seven groups as follows.

1. Waste from overproduction – If the products are made into stock without an arrived order, maybe only as a measure of precaution, it is overproduction. This is often mentioned as the most serious form of waste because it also causes other wastes.

2. Waste of time – Includes cases when a product is waiting for access to the next stage or the product is expected to be completed from the previous phase. Machine breakdowns and material shortages also cause waiting.

3. Transportation waste – This means, among other things, transferring products to and from the warehouse between different manufacturing stages. It also arises if consecutive stages are far apart and the products have to be transported between them, even back and forth.

4. Inventory waste – Wasted inventory consists of over-produced finished products, too large quantities of raw materials, and all work in progress that collects into buffers between work stages. Delays in deliveries or production disruptions remain hidden and cannot be solved if large inventories are kept.

5. Processing waste – Appears if the product is made in higher quality than the purpose of use requires or what the customer is willing to pay.

6. Waste of motion – Any additional human movements, or motions needed to perform a job such as searching for or retrieving parts and tools.

7. Waste from product defects – Includes all kinds of quality defects, such as products that require reprocessing or are completely ruined.

For the reader, it would surely be the simplest if every waste would be followed by a specific tool for removing it. However, it is not an appropriate way to study this issue, as often one measure affects a couple of wastes at once, and sometimes the elimination of one waste requires the co-operation of several techniques. The following two chapters discuss these methods, which are the reasons why JIT production is as effective as it is.

2.3.2 Pull System, Kanban, and the significance of layout

It is advisable to keep factories and production units small, which reduces bureaucracy and makes operations easier to control. At its most extreme, one factory can only be focused on producing one product when all activities can be optimized as economical as possible. (Khanna 2015, 442.) Regardless, the JIT system is suitable for manufacturing product families (products with similar principles) so the extreme optimization is not essential unless production volumes are really high (Haverila et al. 2009, 428).

Control of JIT production can be carried through the pull system. It means that every operator requests or pulls parts from the previous stage of production only for the immediate need. (Haverila et al. 2009, 422.) The principle of the pull system is shown in Figure 3.

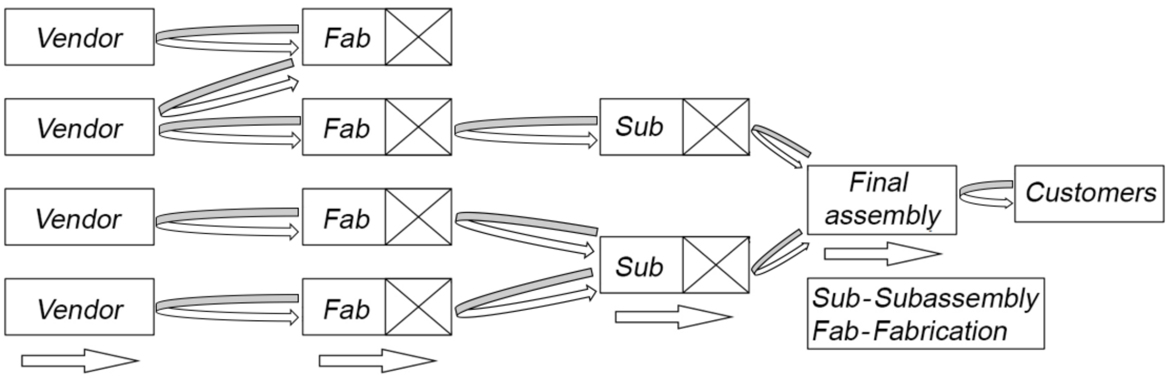

Figure 3 Schematic diagram showing the pull system (adapted from Khanna 2015, 441).

Once the product has been sold to the customer, the distributor pulls another piece from the last stage of production. In the example of Figure 3, this stage is the final assembly, which consequently pulls the parts or subassemblies needed to make a new product from upstream. In this fashion, the chain reaction proceeds all the way up to the raw material supplier. (Khanna 2015, 440-441.) In practice, the system calls for small intermediate storages where the goods do not stay a long time. Consumption of items gives an impulse to place a new order and the storage space will be refilled. (Haverila et al. 2009, 422.)

The impulse for the delivery can be transmitted through a Kanban system, which is a visual way to express the need for parts or materials. The Japanese word Kanban can be translated as a visual card, but other tools can also be used instead of the card. For example, an empty box, a free shelf space, or a specific colored light may indicate that supplement is needed. All different means are still based on the original idea, where the Kanban card goes attached to the article. When the object is consumed, the card returns to the previous stage, that is, the point at which these items are manufactured. It is never allowed to produce more than there are free cards. (Khanna 2015, 444-445.)

Compact layouts must be designed for production units, and material flows must be clear and rectilinear (Haverila et al. 2009, 428). Similar working phases and the machinery needed to accomplish them will form independent groups where employees work in close cooperation. The occupational safety and quality of products will improve as employees get to know their work well. The need to move products and materials back and forth between different units will disappear when all pieces of work needed in one production phase can be done in the same place. (Khanna 2015, 442.)

2.3.3 Short set-up-times, uniform plant loading, and standardization

One of the key concepts of JIT philosophy is the minimization of setup times, which made the Japanese stand out from the Americans in the 1970s. Traditionally, existing times were just accepted and the optimal production batches were calculated based on them. However, the attitude of JIT production is that the optimal batch size is one piece and the setup times are attempted to minimize or completely removed. The setup times can be divided into internal and external, from which the external refers to settings that can be made without stopping the machine. By developing techniques and methods the time taken for the operations can be shortened, or at least many actions can be moved from internal to external. (Khanna 2015, 446.)

JIT production works efficiently when the speed of manufacturing is steady. Therefore, it is not advisable to respond to fluctuations in demand by varying production rates, but by spreading the load over a given period. This can be explained by example, where one needs to produce 10 000 pieces of A-model, 5000 B-models, and 5000 C-models monthly. If different products were made on alternate days, it would increase inventories, which is not desired in JIT production. Thus, the models have to run in sequence A, B, A, C, and so forth on the production line. The manufacturing work of all models must be divided into equally long stages so that the line proceeds smoothly. By this means, all capacity can be utilized efficiently and each model is completed regularly and in the right quantities. (Khanna 2015, 443-444.)

All operations should be standardized to know their content, order, timing, and outcome. Only then will one be able to notice whether the work progresses as expected. Standardization also involves the creation of workstation-specific tool sets, the predictive maintenance of machines, and general tidiness and cleanliness. In addition, co-operation with subcontractors and suppliers needs to be developed and clear rules established to ensure that also deliveries come just in time. (Khanna 2015, 447-448.)

Quality defects or machine breakdowns will readily stop the entire production, as JIT philosophy does not urge on keeping safety inventories. This may sound like a harmful principle because the interruption of production will cause considerable costs. However, the purpose is that due to the clarity of JIT production, the sources of the errors are more easily detected. If the disruption does not stop the production, it will be corrected without a fanfare. It brings on costs as well, but the real root of the problem is not revealed and it can recur. Instead, if production comes to a halt, the situation must be solved immediately and the cost involved is only one-off. (Haverila et al. 2009, 429.)

2.4 Managing production disruptions

Regardless of the forms of production or methods used to manage them, different disruptions are always conceivable. In custom production, shortcomings in technical documents, such as drawings, can inflict flaws on products. Manufacturing can also call for a tool or a machine that is not already available and getting them takes extra effort. Delays in material deliveries, workers’ absences, and machinery breakdowns cause confusion in all production forms. Additionally, customers may make unexpected changes to order volumes, required delivery times, or the desired characteristics of the product. (Kivistö 2015, 3.1.5.)

Pre-designed protection mechanisms for the production system, such as safety inventories or additional machine and labor capacity, are called **formal actions**. In turn, **informal actions** are applied on a case-by-case basis, and examples of such operations are additional subcontracting, partial deliveries, or short term production re-planning. Occasionally, materials reserved for other jobs may also be deployed or the order forced through the production disregarding of adverse effects on other activities. (Häkkinen 2003, 33-34.)

In case of problems and disruptions, it would be good for a company to have a documented system for managing exceptional situations (Kivistö 2015, 3.1.5). However, one may ask whether it is profitable to base a system for fixed protection methods because then all available capacity will not be utilized efficiently and capital will be tied up in vain. If the situations, giving rise to informal actions, are comprehensively identified and an operating plan against them made in advance, there is no need for hasty decisions in case of disturbances. Thus, issues can be solved on an individual basis, but still systematically and cost-effectively without the need to bind resources permanently.

2.5 Defining the critical item

It is practically impossible to find a general definition for the term *critical item* because every company makes the definition from their own point-of-view. The Finnish PSK 6800 standard (2008, 2) describes criticality as a characteristic, that expresses the magnitude of the risk associated with the item. The risks refer to unacceptable consequences such as injury to people, significant material damage, or production losses. According to the standard, the objective is critical if the risk is higher than can be allowed.

Business dictionary (WebFinance Inc, [Ref. 3 March 2019]) defines critical items as components, materials, or systems that are essential for the operation of the company and whose failures could pose a risk to personnel safety. The dictionary adds that also items which are in short supply, have a long lead time, are expensive, have high maintenance requirements, or require special treatments can be found critical. Maintworld magazine (2017) gives a more concrete example of this topic, presenting that a critical item can be a spare part, the lack of which causes excessive downtime in production machinery.

Definitions of this kind are very subjective, because if something is significant, expensive, or excessive for some company, it may not be the same for the other. For that reason, it is important to convert subjective to objective by defining concrete numerical values for criticality assessment. With values, it is easy to notice whether one item is more critical than another. (Maintworld magazine 2017.)

Criticality assessment can be done by different methods, depending on what type of item, machine, spare part, or software, is in question. The following example illustrates a method for calculating the criticality index, according to which the items can be ranked. The method is based on identifying the existing risks, and some of the necessary source data is shown in Figure 4. The example concerns a production machine, but this method can also be applied to assess the criticality of other types of objects, by modifying the risk definitions and weightings as needed.

<table>
<tr><th>Weighting factor [W]</th><th>Time between failures [p]</th><th>Multiplier [M]</th><th>Selection criteria</th></tr>
<tr><td rowspan="5">Environmental risks

$W_e = 20$</td><td rowspan="10">1 = Long time between failures, eg. over 5 years

2 = Quite long time between failures, eg. 2 to 5 years

4 = Quite short time between failures, eg. 0,5 to 2 years

8 = Short time between failures, eg. 0 to 0,5 years</td><td>$M_e = 0$</td><td>No environmental risk</td></tr>
<tr><td>$M_e = 2$</td><td>Minor environmental risk</td></tr>
<tr><td>$M_e = 4$</td><td>Moderate environmental risk</td></tr>
<tr><td>$M_e = 8$</td><td>Major environmental risk</td></tr>
<tr><td>$M_e = 16$</td><td>Serious environmental risk</td></tr>
<tr><td rowspan="5">Production loss

$W_p = 60$</td><td>$M_p = 0$</td><td>Non-operation of equipment has no impact on the sub-process or department</td></tr>
<tr><td>$M_p = 1$</td><td>Non-operation of equipment stops the sub-process or department momentarily (eg. ≤3 h)</td></tr>
<tr><td>$M_p = 2$</td><td>Non-operation of equipment stops the sub-process for a short time (eg. ≤10 h)</td></tr>
<tr><td>$M_p = 3$</td><td>Non-operation of equipment stops the sub-process for a considerable time (eg. 10 to 24 h)</td></tr>
<tr><td>$M_p = 4$</td><td>Non-operation of equipment stops the sub-process for a long time (eg. >24 h)</td></tr>
</table>

Figure 4 The criticality factors of an imaginary production machine (adapted from PSK 6800, 8).

First, a weighting factor W is determined for the different risks, depending on whether the assessment emphasizes financial effects, personal safety, environmental protection, or some other area. The machine of the example does not pose a significant environmental risk when broken, so it weighs 20%. Instead, it will seriously disturb production if the device is completely out of service: 60% of the output of the entire plant will be lost in such a case. Similarly, the weighting factor can also be defined for other risks such as repair costs, safety issues, and quality, but for reasons of simplicity, this example is not so extensive. (PSK 6800, 8.)

The second column in Figure 4 contains different values for the factor p which indicates the lifetime of the device. The last factor, multiplier M, is selected based on the magnitude of the effects of the risk. Multipliers normally grow linearly, for example 0, 1, 2, 3, 4, but if the risk is very serious, such as the risk to the safety or the environment, the growth is exponential, such as 2, 4, 6, 8, 16. Based on this information, the formula can be formulated as follows: (PSK 6800, 8.)

$$K = p * \left(W_e * M_e + W_p * M_p\right) \tag{1}$$

Assuming that the machine is susceptible to damage less than once every five years, the breakdown would cause a minor environmental risk and would stop production for less than ten hours, the values p=1, M_e=2, and M_p= 2 can be read from the table in Figure 4. When the weighting factors are also taken to the calculation in a decimal form, W_e=0,2, W_p=0,6, a criticality index of 1,6 is obtained. It is obviously not possible to conclude from a single result whether it is a lot or a little, but now a concrete numerical value has been achieved. Once all parallel machines are determined in the same way, they are easy to grade based on criticality.

3 SUPPLY CHAIN MANAGEMENT

A supply chain is a network of all the companies and operations through which the product goes on its way from raw material to the final customer (Hugos 2006, 2-3). The supply chain management differs from traditional logistics in such a way that logistics typically refers only to transportation activities between single companies. The supply chain management includes transportation as an important part, but also the coordination of production, inventory, location, and information is a part of it. (Hugos 2006, 4-6.) This chapter presents the principles of each topic, except for production as it was widely discussed in the previous chapter.

3.1 Goals of the supply chain management

The supply chain is not a new invention; already historical strategists such as Alexander the Great and Napoleon understood the importance of the good supply of the troops. Their armies were victorious because of functioning logistics structures, in other words, due to efficient supply chains. (Hugos 2006, 7-8.)

Hugos (2006, 4) writes that supply chain management tries to achieve “the best mix of responsiveness and efficiency for the market being served.” According to his book, these requirements are often contradictory as, for example, a high level of customer service requires large inventories, but cost-efficiency calls for reducing them. When the products are bought into the warehouse, the money is out of the company’s other activities, and the revenue is lost because that capital cannot be invested in productive subjects. Too small inventory can cause lack of parts and consequently bring on a production disruption. That may prevent the company from reaching the promised delivery times and quantities thus increasing the number of complaints. (Haverila et al. 2009, 444-445.) A company should be aware of the inconsistencies in these requirements and make choices in each sub-area of the supply chain management that supports its own strategy implementation.

3.2 Inventory

At a general level, it can be said that an inventory always occurs when at any point during the supply chain the flow of material is stopped (Kivistö 2015, 5.1.5). Almost every company needs stocks of some kind, and the main function of storing is to ensure that the next stage in a supply chain can run without interruptions. Inventories are needed for different purposes, but unnecessary materials should not be stored. (Haverila et al. 2009, 445-447.)

This topic is divided into two parts. First, different ways to classify inventories are discussed, and then the formulas for calculating inventory levels are presented.

3.2.1 Inventory classification

Inventories can be classified in many ways, depending on the viewpoint. In accordance with the *item properties*, one can define production, MRO, in-process, and finished goods inventories. These types of inventories are usually found in every company with manufacturing production. (Aswathappa & Bhat 2010, 463; Kivistö 2015, 6.2.1.)

Production inventories consist of production materials, such as raw material as well as subcontracted parts and components for assemblies. There are two general types of items stored in the production inventories: special items tailored just for the company's needs and standard items, such as metal sheets, bolts, and nuts, used throughout the industry. (Aswathappa & Bhat 2010, 463.)

In-process inventories appear on the production line at the locations, where sequential stages are not in continuous synchronization (Aswathappa & Bhat 2010, 463). For example, if a welding plant operates in two shifts, producing a quantity of products that will be painted in one shift, then the in-process inventory is unavoidably formed before the paint shop during the second shift. Sometimes products are moved in large batches between the stages, which increases the size of the in-process inventory (Haverila et al. 2009, 446-447).

MRO inventories include maintenance, repair, and operating supplies, such as lubricants, cleaners, and repair parts for machines. The connecting factor is that they are not used as a part of the product, but they are needed to make the production possible. (Aswathappa & Bhat 2010, 463.)

Finished goods inventory is a place for complete products that are waiting for the shipment to customers. The size of the inventory depends on whether the production is managed by the inventory level or customer orders. If products are manufactured just after the customer's order, the inventory of finished goods is small and the products only wait for the shipment. Otherwise, the products may be made in advance and stored to wait for the order when the inventory is usually larger. (Aswathappa & Bhat 2010, 463; Koski 2015, 6.)

It is also possible to make the classification considering the *purpose of the inventory*. For example, production inventory or finished goods inventory can be further divided into three parts: a cycle, buffer, and safety inventory as shown in Figure 5. (Koski 2015, 59.)

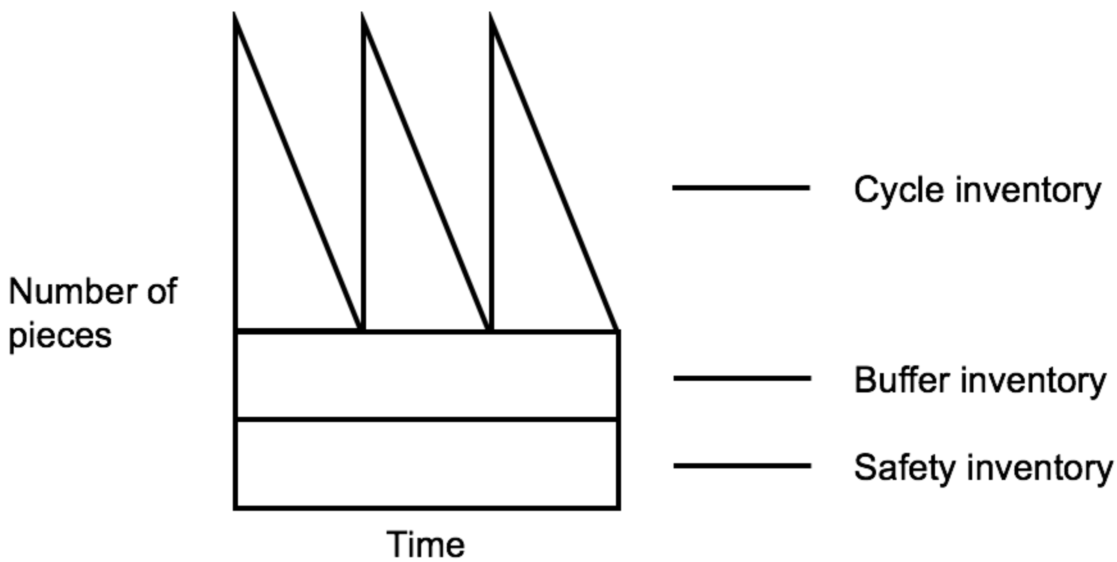

Figure 5 Classification of inventories by the purpose of use (adapted from Smalley 2009, 20, according to Koski 2015, 59).

Cycle inventory is dimensioned by regular consumption. In Figure 5, the peak indicates the moment of supplementing, and the slope illustrates that the inventory is running out before the next delivery. If the dimensioning is done correctly, there are not any products left when the shipment arrives, but there is no shortage of them either. (Aswathappa & Bhat 2010, 463.)

Buffer inventory is a protective measure against fluctuations in consumption. It is also needed if the manufacturing lead time is longer than the desired delivery time. The higher service level a company wants to maintain, the larger the buffer inventory needs to be. On the other hand, the size of the inventory can be reduced with better demand forecasts. (Haverila et al. 2009, 446.)

Safety inventory is used to prepare for disturbances in production. Such things are, for example, machine breakdowns, quality problems, and delayed raw material deliveries. In practice, this means that the company can still meet all the orders by resorting to stored products, even if production would be interrupted. (Koski 2015, 60; Haverila et al. 2009, 447.)

It is also possible to name, still *according to the purpose*, seasonal, pipeline, and obsolete inventories as well as inventories for an economic batch size. **Seasonal inventory** is filled up slowly when the sales are low, as production is unable to fulfill the needs when demands begin to grow exponentially at the start of the season (Aswathappa & Bhat 2010, 463). When items need to be moved between companies, **pipeline inventories** are created due to the formation of reasonable transport batches (Haverila et al. 2009, 447). **Obsolete inventory** consists of the items that no longer have commercial use, for instance, if the product version has changed or the contract with a particular customer has expired (Kivistö 2015, 6.2.1). If there are long setup times in production, the costs of making the settings are high, which forces to create **inventories to ensure economic batch sizes** (Haverila et al. 2009, 447).

At the same time, the inventories can be sorted *by type*: it can be thought that there is an active and a passive part. **Active inventory** is the part which is running out before the next supplement arrives, for example, as the cycle inventory described above. **Passive inventory** includes everything above the active inventory and it should be carefully kept under control. Usually, everything that is beyond necessary for buffer or safety purposes is entirely useless. The excess passive inventory is commonly accumulated by inaccurate demand forecasts. (Kivistö 2015, 6.2.1.)

3.2.2 Calculations of inventory level

Defining inventory levels is varying at the different production stages. In the case of the production inventory, calculations are mainly influenced by the features of the supplier of raw materials, such as the delivery reliability or intervals of shipments. In turn, when dimensioning the finished goods inventory, a company should also consider characteristics of its own production. (King 2011, 34.)

Following calculations are based on the inventory structure presented in Figure 5, so this chapter introduces how to define the sizes of cycle, buffer, and safety inventory. Mainly, in this text, they are thought to be parts of the *production inventory*. In order to provide a broader understanding about this subject, the calculations of the safety inventory (formula number 4) are presented as it would be part of the *finished goods inventory*, and essential differences are explained at the same time.

Contrary to the previous chapter, the literature also suggests definitions that do not separate the buffer and the safety inventory from each other (Aswathappa & Bhat 2010, 463; King 2011, 34-35). In such cases, the formulas determining the size are combined so that they take into account the properties of both. However, the difference is considered in this text, thus the following formulas are split into their basic form.

Size of the cycle inventory can be calculated simply, as only two factors are required for it. The first is average demand D_{avg}, which indicates how many pieces of an item are spent daily. The second factor, delivery cycle DC, means the period how often a new shipment arrives. The formula is as follows: (Aswathappa & Bhat 2010, 463.)

$$Cycle\ inventory = D_{avg} * DC \qquad (2)$$

If a company uses every day 1000 pieces of some item in their production, and the supplement is every fifth day, the maximum size of the cycle inventory (and the order quantity at the same time) is 5000 pieces. The calculation is naturally guided by the supplier's possible restrictions on order quantity or delivery dates.

When **dimensioning the buffer inventory**, one must define the desired *service level*. In practice, the term means that if a company responds to customer demands in all circumstances, then the service level is 100%. The lower the service level is, the less likely the company can respond to large consumption fluctuations directly “off the shelf”. It may not be financially viable to seek the best service level with every customer and every product. (Koski 2015, 59-60.)

Once it is decided which service level is wanted to achieve, one needs to define a *service level coefficient* for calculation. It is not a complicated thing after all, but some background information is needed to understand it. In statistics, the concept of a normal distribution (or Gaussian distribution) is known and used to determine statistical probabilities. One statistical figure, Z-score, can be determined based on the parameters of the normal distribution and used as the service level coefficient. It is not appropriate to go deep into this topic, at this point it is only essential to understand that the dimensioning of inventory levels is based on an estimate of how likely the variation in demand will cause the inventory to run out. (Finnish Online UAS, [Ref. 29 January 2019]; King 2011, 33-34.)

Based on the desired service level percentage, the Z-scores can be calculated, for example, in Microsoft Excel spreadsheet program with the function NORM.S.INV. The service level is entered into the function in decimal form, providing the Z-scores as output. (Koski 2015, 59-60.) Table 1 shows some examples of this.

Table 1 Examples of the service level coefficients

Desired service level	Decimal conversion	Service level coefficient (Z-score)
85	0,85	1,04
90	0,90	1,28
95	0,95	1,64
99	0,99	2,33
99,9	0,999	2,09

The service level coefficient Z is thus the first factor for calculating the size of the buffer inventory. Secondly, the standard deviation σ_D is needed, and it means variation in the consumption of the item. The deviation is not compelled to define on a daily basis, but it may come from the longer period. The length of the observation time is the factor T. The above-described delivery cycle is also required, and the formula is as follows: (King 2011, 34.)

$$Buffer\ inventory = Z * \sigma_D * \sqrt{DC/_T} \quad (3)$$

If a 95% service level is tried to achieve, the service level coefficient is 1,64 (according to Table 1). If consumption of the item has been calculated for two days, when it has varied regularly between 800 and 1200 pieces, T is 2 and σ_D is 200. The deviation is thus determined by comparison with the mean, not between the extremes. Finally, if the same delivery cycle is used as above (5 days), the size of the buffer inventory will be 519 pieces in this example. In practice, that means that the buffer is sufficient for 95% of the time, and thus in 5% of the cases the buffer runs out, and the production is interrupted.

Occasionally it is defined that a good **size for the safety inventory** is 10-20% of the cycle inventory (Koski 2015, 60; Rădăşanu 2016, 149). If so, resting on the previous example of the cycle inventory (where the size was calculated to be 5000 pieces), the company would hold 500-1000 items as the safety inventory.

According to the King (2011, 34), the level of the safety inventory can be calculated more precisely by using the service level coefficient Z. In this case, also the factor for the lead time variation, σ_{LT}, is needed. Now, as was discussed in the first paragraphs of this chapter, it is crucial to remember at what stage of production the inventory is. For example, at the beginning of the production line, the factor σ_{LT} would be defined by delays (due to the supplier) in delivery lead times. However, since it was previously stated that this calculation will refer to the finished goods inventory, now σ_{LT} describes how much the *manufacturing* lead time varies. For the same reason, the average demand D_{avg} means the *sales of a finished product* in this case. The formula is as follows:

$$Safety\ inventory = Z * \sigma_{LT} * D_{avg} \quad (4)$$

If trying to achieve a 95% service level also in this example, Z is 1,64. Assuming that manufacturing the product sometimes takes one day and sometimes two, σ_{LT} is 0,5 day (again fluctuation *from the mean*). As the average demand, it is sensible to use the same value (1000 pieces) as earlier, as this allows for a scale comparison even when talking about a different product. Simple multiplication gives a result that there should always be 820 pieces of this product for safety purposes.

3.3 Location

A location refers to how the company has geographically placed its facilities: in which cities and countries the units are located and how large they are. Location decisions are huge choices as their implementation requires much capital and binds it for a long time. The decisions must be carefully considered, as they are not only about spending money, but they are also communication about the strategy. The geography reflects how the company can produce products and services on the market. (Hugos 2006, 13-14.)

For example, in Scandinavia, recent changes have taken place in the location decisions of the banking sector due to digitalization. Some banks have reduced and will continue to reduce the number of branches and cash services, and have emphasized the development of online bank services. In this way, they are profiling themselves (intentionally or unintentionally) to take account of a different customer base than banks who attach importance to a broad network of branches and personal customer service. It cannot be said that the other style would be better than the other, but the company should be aware of the importance of location decisions to the image.

The location has an impact also on supply chain costs and performance. The cost of labor and facilities will rise rapidly if a company wants to operate in several different places. There may be regional differences in taxation and other similar charges, especially when comparing two cities in different countries. If a company wants to serve customers as flexible as possible, it often requires small branches in many areas. For instance, small grocery stores or fast food restaurants have spread widely so that even within the same city or district there can be several outlets. If, on the other hand, the company wants to emphasize cost-effectiveness, then large centralized units will come to the question. (Hugos 2006, 14, 36.)

It is also noteworthy whether the company distributes various operations to different locations or whether all sites are identical. This naturally depends on the company's business: the grocery store may be similar in many places, but for the manufacturing company it may be worthwhile to concentrate on the production of one product to one factory. (Hugos 2006, 13-14, 36.)

The location of premises from the perspective of customers and suppliers is one of the most important factors for success. The prosperity of the business also depends on the competitors, so a better-placed company often has an advantage. A harder-to-reach company may win the competition up to a certain limit if it offers a product or service at a lower price than others. The farther the company is from its customers or suppliers, the higher the price of the product will be when the cost of transportation increases. In addition, if personal customer service is a key element of the activities, it is crucial that the office is located so that customers can easily arrive there. (Somerla 2007, 8.)

The good location attracts employees to work for a company (Somerla 2007, 7). This can also be thought the other way around: good employees attract companies to their area. The latter claim refers to the fact that getting skilled labor is not a matter of course in all regions. The creative industry is often located close to science universities and technology-based companies are set up in the environment of technical universities (Somerla 2007, 9). Thus, cooperation between the schools and the companies is fluent and both benefit from each other.

However, such symbiosis is neither an axiom nor lifeblood. The closeness of the educational establishment is not enough if the region does not entice people to stay after the studies, and on the other hand, the skilled workforce can be found elsewhere than university cities. One factor that enhances regional attractiveness is a functioning infrastructure. From the standpoint of industrial companies, it includes traffic connections with capacity for large freight volumes, smooth public transport, and adequate parking facilities (Somerla 2007, 8-9).

The size, number, and location of the premises determine the possible routes of the product through the supply chain (Hugos 2006, 14). More about these routes and their features are discussed in the next chapter.

3.4 Transportation

Transportations can be performed in many ways and the product often does not pass through a direct route from the sender to the recipient with only one vehicle. This chapter approaches the subject from two perspectives: different transport modes are presented first, and the planning of deliveries is discussed after that.

3.4.1 Different transport modes

The location discussed in the previous chapter affects the choice of the transport mode, as not all companies can be located near the same facilities, such as an airport or railway. Also, the features of the product may bring on limitations and a large part of the decision is a juggling a speed and a cost. Products can be moved on land, at sea, in the air, and even on information networks.

Because **ships** are now large and, due to the container technology, easy to load, they are a cost-effective solution for transportation. Regrettably, although the use of containers has accelerated the handling of cargo in ports, it is still time-consuming. Together with long journeys, it makes shipping the slow mode of transport. The use of the ship is limited by location factors, as the ports can only be located next to navigable waterways and transportation between the harbor and inland must be handled by the other modes of transport. (Hugos 2006, 14.)

Sea transport is mainly organized in three alternative ways. Liner traffic runs according to timetables and its route is planned to pass through certain ports. Instead it, tramp traffic does not have fixed schedules but operates by case-specific agreements. Their intermediate form is contract traffic, which means that the customer has rent the entire ship. There are also regional versions of this division, so it is not entirely unambiguous. (Karrus 2001, 116.)

A **train** is also an economical option and has the advantage of carrying large (heavy) loads., but the coverage of the railway network limits its use. At best, it has its own dead-end track to the production plant, but at worst, the railway does not even pass through the city. The problem with railroad transport between countries is that there are different track gauges. Rail transport is closely coordinated and timed because other traffic, such as passenger transport, also travels on the same lines. (Karrus 2001, 117-118.)

The trains are considered environmentally friendly because low rolling resistance and high transport capacity allow low emissions per tonne transported even though diesel locomotives are used. On the railroads, the goods can be carried in containers, in special wagons tailored for the product, or as a combined transport in where the full truck is driven onto the train. (Kivistö 2015, 4.5.2, 4.5.5.)

Pipes are particularly suitable for transporting gases and liquids, but Karrus mentions in his book (2001, 120) that they can also carry some solids. The book does not give an example for the solids, but is likely to mean different powders or granules that are often transferred in pipes within industrial plants. In addition to short internal transfers, the pipe can convey goods over long distances, and at least oil and natural gas are transported in such a way (Ruska, Koljonen, Koreneff & Lehtilä 2012, 22, 47). The pipelines are also used for the water and heat distribution, as well as for sewerage, utilizing the ability to transfer large quantities of substances. Building the line requires large investments, so it is a sensible option only if the transport is continuous, the volumes are high, or the need continues for a very long time. (Karrus 2001, 120.)

Road transport is the very flexible mode of freighting, as the vehicle can reach almost everywhere if there is a passable road. Due to flexibility, it is also relatively fast, even though there may be some disruption in traffic or variations in road condition. The driver can often choose the best of the routes to get the load to the destination as quickly as possible. One thing that cannot be influenced is the fluctuation in fuel prices, which has a direct impact on transport prices. (Hugos 2006, 15.)

Road transport can be carried out by passenger cars, delivery vans, trucks, or buses, and the vehicle must be selected considering the features of the load, route, and destination. There may be weight limited bridges or cramped yards, and besides, the local law defines the maximum permissible dimensions and weight. Other restrictions, such as limited access on account of the emission category of the vehicle, may exist too. (Kivistö 2015, 4.4.)

Air transport is characterized by speed, reliability, and a high price. The use of aircraft is limited by the location of the airports and by airlines' restrictions on the dimensions and weight of the products. Air transport is a sensible option if the product being transported is relatively valuable in view of the size (e.g. electronics) or the condition of the product requires fast delivery (e.g. food). Due to the geographical location of the shipping point and destination, transportation by land may require several different modes of transport which causes extra handling. In such cases, air transport can avoid delays, costs, and damage to products resulting from handling. The speed of air transport is especially useful if the product loses its topicality quickly (e.g. spare parts). (Kivistö 2015, 4.7.1, 4.7.2.)

The fastest and most flexible mode of transport is **electronic transport**. The construction and maintenance of power lines and information networks incur expenses, but their use is very cost-effective. The problem is that a range of products delivered through it is very limited. Only digital products such as music, movies, pictures, and texts can be conveyed by this means. An electronically transferable raw material could be a data (needed for the creation of mentioned products) and electricity. (Hugos 2006, 15.) Although a company would operate in such an industry that the digital deliveries are not feasible, it still can take advantage of the benefits of digitalization, for example, for sending invoices or transport documents, tracking shipments and receiving payments.

3.4.2 Delivery scheduling

If a delivery is made straight from the dispatching location to the receiving site, it is called a **direct delivery**. The products can be picked up from the place where they are made or stored and delivered to a destination where they will be used or sold. Transportation is easy to plan, as one only needs to decide what the fastest route between the two locations is. The products basically cannot be lost because they do not need to be handled during delivery. If the sender loads the right products, they will also arrive unless something unexpected happens. (Hugos 2006, 91.)

In the case of the direct deliveries, the size of the batches and the frequency of shipments must be considered. The quantity to be sent should be such that the transport unit becomes full because it is not cost-efficient for the transport company to take partly empty loads. If small batches are significant for the consignee, the other types of deliveries are appropriate. The advantages of the direct deliveries are the simplicity of operations and ease of delivery coordination. (Hugos 2006, 91.)

If the transportation includes more than one sender, it is so-called **milk run delivery**. In many cases, the rearrangement of consignments is profitable, especially if the products from several different suppliers to one recipient pass through the same forwarder and only a small number of items come from each supplier. For the arrangement, the forwarders have specific warehouses called cross-docking centers. There, the loads from different suppliers will be unloaded and all products going to one recipient will be packed together in one truck. Eventually, only this one truck will be sent to the destination. The term *milk run delivery* also covers cases with multiple recipients. If each of them needs only a few pallets, everyone can be served by one truck passing through all receiving locations. (Hugos 2006, 92.)

Scheduling milk run deliveries is not as simple as scheduling the direct transports. Choosing the quantity of products and the frequency of shipments is no longer enough, but also (and this is the most important), one must consider the routing and sequencing of pickups and deliveries. If the products are loaded in the wrong order in relation to the unloading points, it will cause extra handling and slow down the work. Poor route choices can cause crisscrossing which takes time and increases transport costs. If scheduling is done correctly, milk run delivery is a very cost-effective way of transport. (Hugos 2006, 92.)

An essential part of transport planning is **reverse logistics**, where items are transferred from customer to supplier. It includes returns, warranty repair shipments, recycling, as well as packing units such as roller cages and pallets. Forecasting reverse logistics is complicated because the returnable items accumulate irregularly. Its management is still important in order to maintain customer satisfaction, particularly in the case of warranty repairs. The returns must be effective also if the supplier needs the packing units for its own operations. An example of this is when a transport rack of products is used as a mounting support in the assembly. (The World of Logistics, [Ref. 16 March 2019].)

3.5 Information

Information in this context refers to the data collected during the supply chain and shared between companies. It links all the activities and operations together and forms the basis to make rational decisions. (Hugos 2006, 15-16.)

The following chapter describes the different forms and uses of information. The effects of transparent data transmission are discussed after that and the last part provides instructions for efficient information processing and transfer.

3.5.1 Different forms and uses of information

The importance of information is constantly growing, as the technologies that enable it to be collected and distributed are increasingly used and developed to be more convenient and less costly. However, collecting and sharing information is not entirely free of charge as, for example, developing and updating electronic systems and communication interfaces involves cost. If one wants to emphasize cost efficiency, the information cannot be shared broadly and handled very comprehensively. Moreover, some companies do not want to open their systems for externals, that nothing valuable information, which can be crucial for a competitive edge, would leak out. (Hugos 2006, 36, 38.)

The responsiveness of the supply chain is higher if companies share more and better information with their partners. The data is gathered from all four other supply chain factors: production, inventories, location, and transportation. The more open the companies are about product supply, customer demand, market forecasts, and production schedules, the better everyone can react to changing market conditions. (Hugos 2006, 18, 36, 38.)

The data can be divided into three different groups. **Master data** is static information about the location, products, resources, and supply chain partners. It usually stays the same for relatively long periods. Various business processes within or between companies produce **transaction data**. Such actions include orders, deliveries, invoicing, and scheduling. **Event data** contains the physical movements of products and transport units at different stages of the supply chain. It is often collected by automated identification methods such as barcode scanning. The time and place, the description (reason for the event), and the product or item in question are things to record as the event data. (Kivistö 2015, 1.3.1.3.)

The information is used for two different purposes. Firstly, it is needed to **coordinate daily activities**, that is, to control the four other supply chain factors. Companies decide weekly production schedules, inventory levels, transportation routes, and stocking locations based on the information available. Secondly, it is utilized for **forecasting and planning**, so that one can respond to customer demand in the right way in the future. The prediction which includes short term operations, such as monthly and quarterly production schedules, is called *tactical*. Longer term actions, such as factory opening or closing decisions are called *strategic* predictions. (Hugos 2006, 16.)

3.5.2 Importance of supply chain transparency

Abundant information makes the supply chain transparent, which enables efficient operating decisions and high-quality forecasts. In order to do profitable actions, the data must be accurate, timely and complete. (Hugos 2006, 16.)

Non-transparent supply chain increases the costs at the boundary of companies involved in it. If it is not known how much and when the customer order, or how the supplier will take care of deliveries, this uncertainty must be compensated by the inventories. Also, if the information is not shared openly, the processes between the supplier ant the client are not easy to get aligned. This may manifest in discrepancies, such as different product codes or incompatible pack sizes, that cause additional work. (Kivistö 2015, 1.1.5.)

One commonly known phenomenon due to poor information transmission in the supply chain is called *the bullwhip effect* (see Figure 6). It often begins when demand increases slightly at the end of the supply chain (close to the final customer), and as a precautionary measure, products are ordered more than really needed. (Hugos 2006, 170-171.)

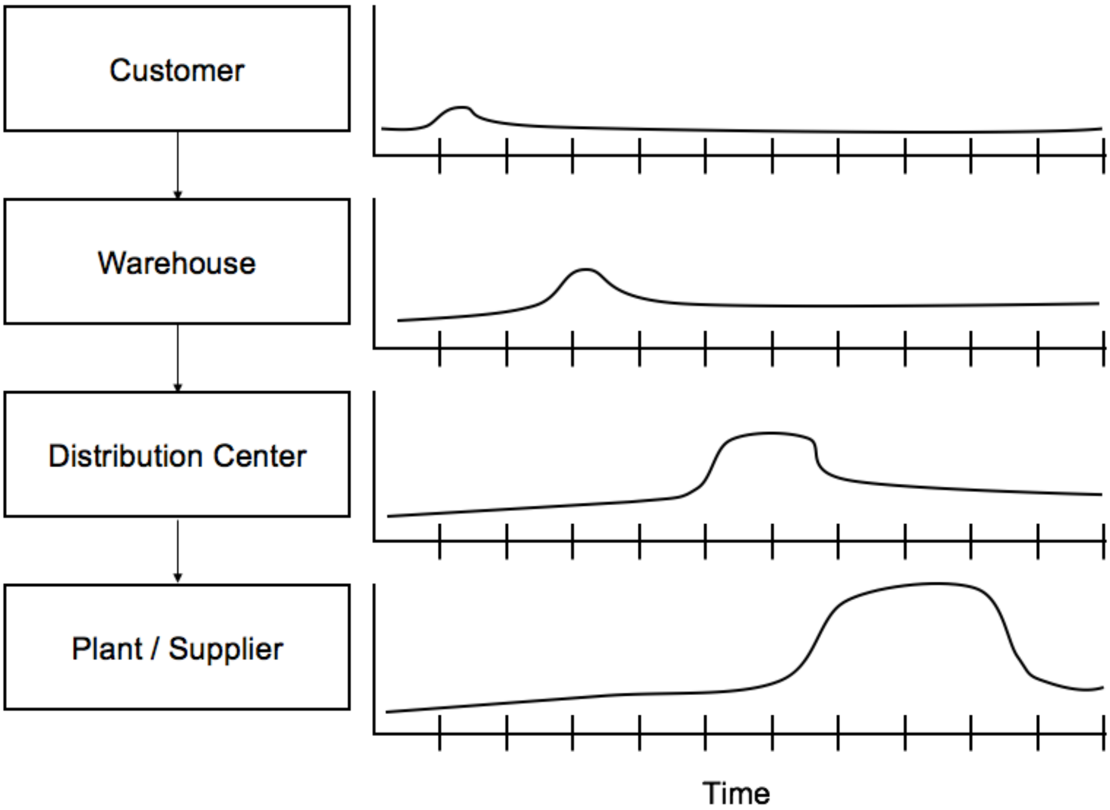

Figure 6 The Bullwhip effect illustration (adapted from Salleh 2013).

As shown in Figure 6, each operator raises the safety factor in the absence of accurate demand information. The longer the mistake progresses in the supply chain, the larger it will grow. The rapid rise in demand produces supply shortages, resulting in further increases in order volumes. It may not sound logical, but it is because subscribers expect thus to get enough products even if the order is delivered as incomplete. Manufacturers step up capacity to overcome delivery difficulties, but stocks are filled up since there are no real sales. Consequently, orders are canceled, the increased capacity has to be cut, and everyone loses money. (Hugos 2006, 170-171.)

If a company develops processes at the expense of its partners, it will not improve the competitiveness of the company or its product in the eyes of the customer. The cost of activities does not disappear when outsourcing, but eventually the final customer pays them. Advanced companies strive to enhance the entire supply chain by reducing costs throughout. When relations between the partners are good, information can be shared and operations developed in collaboration, and the savings affect the entire supply chain. (Kivistö 2015, 1.1.5.)

3.5.3 Efficient information sharing

The supply chains today are more complex than before, as companies operate with a variety of suppliers, subcontractors, and transport partners. Especially the order management process has undergone a major evolution. In the past, slow data transmission methods, such as order forms made of paper, were enough, but modern computerized methods focus on the fast and more accurate movement of data. (Hugos 2006, 88-89.)

In his book, Hugos (2006, 89-90) presents four basic principles to guide the efficient order process.

1. **Enter the order once and only once** – The data should be collected digitally as close as possible from the original source so that it remains unchanged. For example, if a customer writes an order directly into the ordering system instead of doing it by phone, one step in the process is left out and a single work does not take two people. This minimizes the change of information, and in the case of an incorrect order, there is no need to argue whether the customer service person or the subscriber made the error. (Hugos 2006, 89-90.)

2. **Automate order routing** – This rule further underlines the minimization of manual data processing mentioned in the first rule. Processing routine orders should be primarily automated because the risk of human error is high if one needs to copy delivery information, such as product codes or the number of pieces. In addition, the program should automatically check the content of the orders, and indicate if it requires special treatment so that the problems are noticed more easily. Then the information can be forwarded faster to a person who can handle the issue, and thus the customer can be better served. (Hugos 2006, 89-90.)

3. **Make order status visible** – The customer should be able to track the order and delivery without the help of anyone and regardless of the time. If the customer has to call or send an email for asking about the situation, it will again take two people for one task. Further, if the customer does not reach

anybody, waiting without the information may cause other problems. Tracking should cover the entire process from placing an order until the delivery of the products. (Hugos 2006, 89-90.)

4. **Use integrated order management systems** – The information must be transferred between different applications in real time. First, the ordering system needs information about product prices and features so that the customer can make a purchase decision based on them. If the customer orders off-the-shelf products, the order information must be immediately forwarded to the inventory management system to update the inventory level and, if necessary, to create an impulse for ordering or manufacturing the new products. In turn, the inventory level is needed back to the ordering system so the next customer can see how much the product is available. The order information is also transferred to an invoicing system or an online payment system. (Hugos 2006, 89-90.)

Although the previous example treated only the ordering process, the same data processing principles can be applied in other processes. It is important that the data is collected close from the original source and the transfer of it does not require manual steps. In addition, the information must be automatically available for different software and easily accessible for all persons concerned.

4 RESEARCH METHODS

This chapter discusses the theory of research methods to the extent that is essential for the thesis. The summary of the methods used in this work can be found in the introduction (see chapter 1.3), but this chapter explains and justifies the background of the choices. Initially, different ways to group researches are discussed, and it is followed by the differences in quantitative and qualitative approach. The choices related to the acquisition of information and their impact on the reliability of research are considered lastly.

4.1 Classification of researches

When generalized far enough, it is possible to place all investigations under two main categories: theoretical or empirical research (Valli 2015, 1.0). Empirical research is based on experience, it is experimental and observational, and it produces information about the actual, real world. It can be a pragmatic test of a theoretically defined hypothesis or a study of the causes of a practically occurring phenomenon. Also, empirical research can search for a suggestion or solution of how to implement a thing. (University of Eastern Finland 2012, 1.) Empirical research emphasizes the explanation of methods for collecting and analyzing data. Based on these, the reader can evaluate the research, which is an essential part of the credibility of the study and its results. (Tuomi & Sarajärvi 2018, 1.1.2.)

Although empirical research is much more common, there is also theoretical research, which is in many ways a different method. Principally, theoretical research does not make direct observations of the subject itself, but the researcher uses the empirical data collected by others. Based on this earlier material, the theoretical researcher develops concepts and explanations for the phenomenon being studied. (Malmberg 2013, 2, 8, 9.) Theoretical research reporting hardly focuses on describing data collection and analysis but attach importance to the presentation of problem-solving steps. Such steps may include defining the problem, clarifying unclear views, and explaining results. The credibility of theoretical research is mainly determined by how validly the source material is used. (Tuomi & Sarajärvi 2018, 1.1.2.)

There are many different types of research under both main groups. One of them, action research, is essential to this thesis. According to the general definition, action research is a process that explores practical action, but in particular, seeks to change and improve it (Kajaani University of Applied Sciences, [Ref. 5 February 2019]).

Researches can also be distinguished in respect of their time perspective. The cross-sectional study focuses on a specific time and examines the phenomena occurring at that time on the one-off basis. It seeks to give a precise description of an individual, group, situation or phenomenon at the time of research. Instead, the longitudinal study examines the development of a matter over time, for example, by presenting the same questions to the same target group at different times. (University of Eastern Finland 2012, 3.)

4.2 Quantitative and qualitative approaches

The research problem and the purpose of the research together determine which approach is the most preferred: quantitative or qualitative (University of Eastern Finland 2012, 3). Although they have opposite characteristics, choosing one approach does not completely exclude the other. They can be used individually, but when used in parallel, they complement the overall view of the phenomenon. (Haasio 2014.)

Quantitative research explains a phenomena based on numerical data collected from a large population. This approach is interested in different classifications, comparisons and causal relationships and is analyzed in different statistical and mathematical ways. Research answers questions like what, where, how much and how often. (Haasio 2014.)

Qualitative methods give a better understanding about the causes of the phenomenon (Haasio 2014). The analysis is done with a more limited population and the result is desired to be a logical interpretation where nothing conflicts with the big picture. Research answers questions like how, why and what. (Alasuutari 2011, 2.0.)

For example, it is possible to investigate consumers purchasing behavior in the case of cars, using both approaches in parallel. Quantitative analysis answers how many blue and how many red cars have been sold, and qualitative analysis tells you which things have affected the choice of the color. (Haasio 2014.) However, if one wants to study the outbreak of the First World War, only a qualitative approach can be used. There are no historical situations for the comparison, the first of which would have caused the war and the other did not. Therefore, one needs to find a logical interpretation why things have progressed as they are, in this single situation. (Alasuutari 2011, 2.0.)

4.3 The ways of obtaining information and their reliability

Once the approach is known, it is necessary to define what kind of group would be approached. Very rarely it is possible to collect research results from the whole target group or population, but most often choosing the appropriate **sampling** is needed. The sampling could be described as a kind of miniature model of the population. In the simplest form, the sampling is just like a lottery from the entire population, which is a suitable way for small groups whose members have equal characteristics. (Valli 2015, 2.0.)

If the population is not uniform, one needs to find out what kind of segments it is divided into, and how many percent from the whole population each of them is. The crucial thing is that the different members are represented in the right proportion because when the results of research are generalized to the population, the conclusions are accurate enough only if the sampling was successful. Common to all sampling methods is randomness, so each member of the group has the same probability of being selected for the sample. The size of the sample is usually 20% of the population, but in extensive researches sometimes less than 1%. If the target group is tiny, it will not be sensible to choose only a small part of it because it would make the research too inaccurate. When all members are involved in the research, it is called total sampling. (Valli 2015, 2.0.)

The acquisition of material for research can be made by many different methods. Common **data collection methods** include interview, survey, observation, and gathering information from various documents. The methods can be used individually, in parallel, or in combination and the choice of method must be done according to the research problem and resources. (Tuomi & Sarajärvi 2018, 3.0.)

For example, observation provides comprehensive basic information on the phenomenon being studied, so it is a good method if not much is previously known about the subject. In turn, the advantage of the interview is flexibility, when questions can be repeated or clarified, thus reducing the possibility of misunderstandings (Tuomi & Sarajärvi 2018, 3.1, 3.2).

Further, an appropriate indicator must be built to collect the research data. For that, one needs to think carefully about *what* should be measured and *how* they are measurable. A questionnaire is a good tool for collecting large research data, but the investigated matter must be known with sufficient accuracy so that the questions can be placed correctly. If necessary, experts in the field can be used as a consultant. When making questions, the characteristics of the respondents must be considered initially. The results may be distorted if the respondent does not understand the question as the researcher meant. The questionnaire should be clear and contain the answer instructions. Also, it must be pre-tested before distributed to the target group. (Valli 2015, 4.0.)

Selected approaches and ways of obtaining information affect the **reliability of the research** greatly. One way to increase reliability is triangulation because then the researcher cannot commit to only one perspective. Triangulation can be divided into different types and one is data triangulation. It means that research data is collected from several groups with different positions. When various people are doing the research or analysis, it is said to be investigator triangulation. Theory triangulation means the consideration of many different theoretical perspectives. Methodological triangulation involves using different methods in the same research. (Tuomi & Sarajärvi 2018, 6.5.)

5 DESCRIPTION OF THE PRESENT CONDITION

Description of the present condition is divided into two parts in this chapter. The first part outlines the ordering and delivery process in a normal circumstance. The second part explains the steps that will be taken when there is some disruption to the ideal situation. The duties and responsibilities of the different participants, as well as the computer programs relevant to the processes, are described during both parts. This chapter is important to understand the reasoning behind the final results.

5.1 Standard ordering and delivery process

At first, it is reasonable to mention that Volkswagen Group has a shared database of parts and materials for all the factories, which includes plenty of information, such as inventory levels, suppliers, and deliveries. The database can be accessed through a few different applications, and each person uses the user interface best suited to his or her job (one is shown in Figure 8). The systems differ slightly in how they display the information stored in the database, but they are all based on the same material. (Raz 2019.) For the sake of clarity, these systems are hereinafter referred to as an “inventory management system”, regardless of which particular application or interface is used.

At ŠKODA AUTO a.s., the standard procedure of parts order is based mainly on digital systems. The production planners consider the upcoming production based on a forecast and orders and draw up a production plan. According to the production plan, the need for parts for the next few weeks is recorded to the inventory management system. (Kuka 2019.)

Subcontractors and vendors who supply materials, parts, or subassemblies are all together hereinafter referred to as “suppliers”. Each supplier has an access right to the inventory management system, so they receive the information on the need for parts directly through the system. The suppliers are responsible for ordering transportation for parts and they send shipping orders through dedicated software called Discovery (see Figure 7). Discovery is intended for communication between the supplier and the forwarder, and some necessary information such as part numbers and delivery numbers are automatically transferred from the inventory management system. (Kuka 2019.) The “forwarder” refers here (and from now on) to the company providing freight transport services.

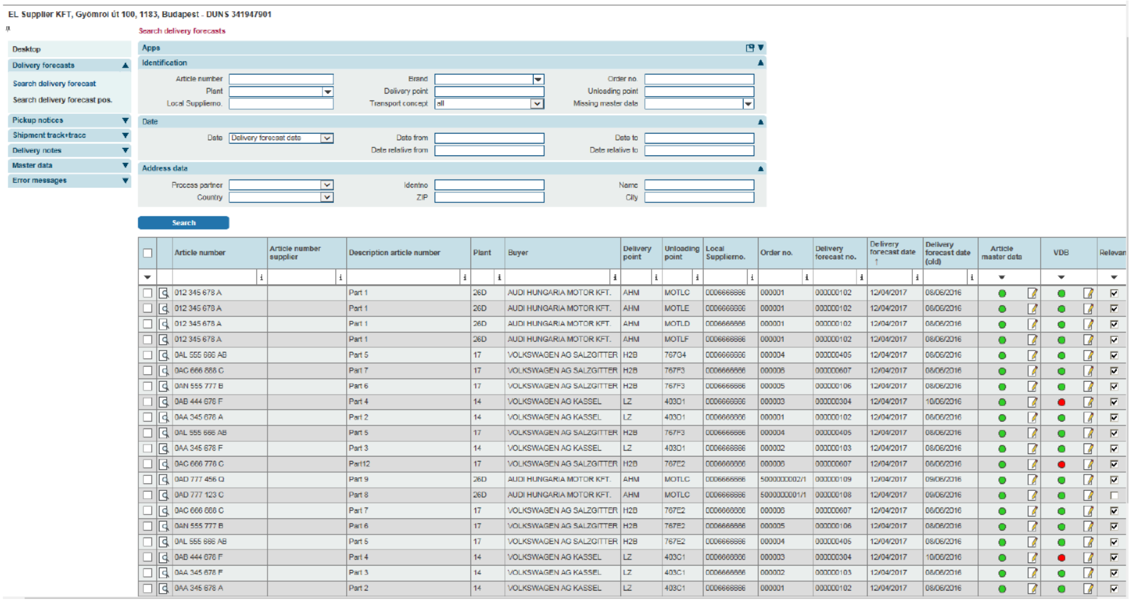

Figure 7 Overview of search delivery forecasts (screen capture from the Discovery-software).

ŠKODA AUTO a.s. has transportation contracts with several European transport companies and the practices are defined in the General Shipping Instructions that are common to entire Volkswagen Group. The forwarder receives the shipping order from the supplier, confirms it, and sends a truck to pick up the products. The forwarder is primarily free to decide whether it will deliver the products directly from the supplier to the ŠKODA AUTO a.s., or whether it will rearrange the load in the cross-docking centers. The supplier enters “master data”, to the inventory management system (shown in Figure 8). The master data consists of information about the shipment, such as mass, a number of pallets, and a truck license plate number. At the time of loading, supplier prints delivery notes, and status *materials in transit* (MAT) is recorded to the inventory management system due to that operation. (Kuka 2019.)

All the contract forwarders have the access rights to Discovery, but not to the inventory management system, so they cannot modify the master data. This means, for example, that if products are loaded into a new truck with a new license plate number in the cross-docking center, this information will not be updated to the system. (Raz 2019.)

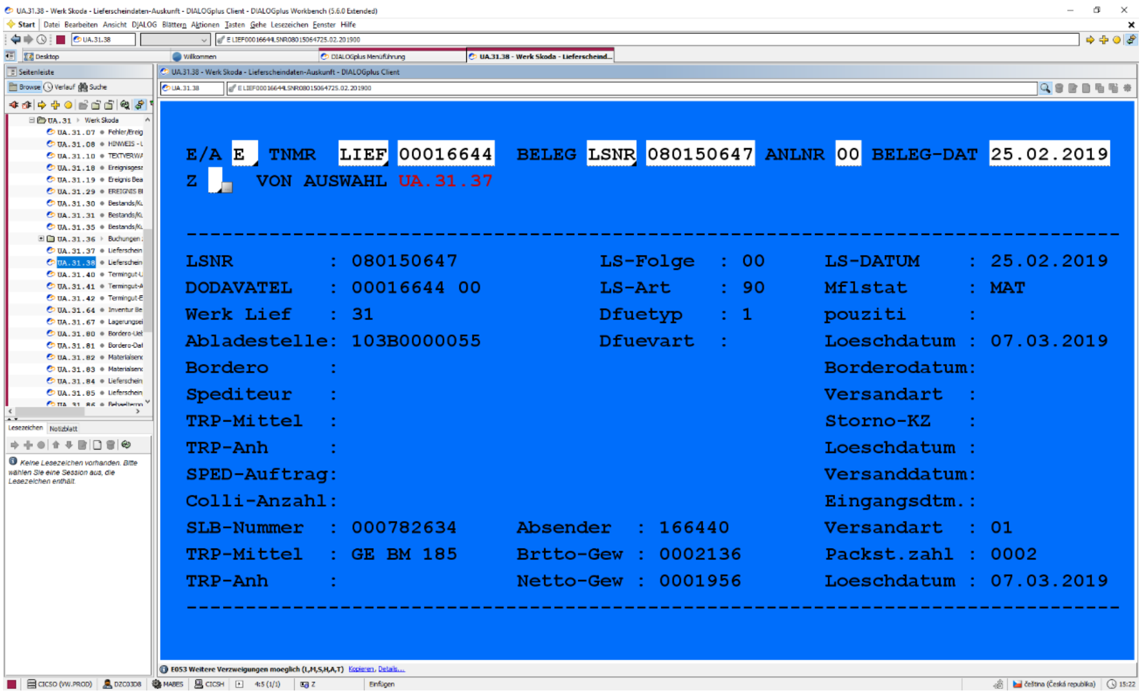

Figure 8 Master data (screen capture from the inventory management system).

Before the truck reaches the ŠKODA factory, the forwarder must reserve a time slot for unloading. Thinking literally, the *time slot* is a slightly misleading term because the forwarder will actually get a *deadline*, by which the truck driver must arrive at the gate for registration. However, the term is in that form in systems, so be it. After registration, the truck remains to wait for a turn to the unloading place. The contract forwarders use the browser-based application called B2B to book a time slot. B2B is connected with software called LKWcontrol (see Figure 9), which is used to track the movements of trucks inside the factory gates. (Raz 2019.)

It is also possible to do the booking by filling a certain form and sending it by email to the gate, where the request is entered into the system. Irrespective of the way the reservation is made (via application or email), the request contains information about delivery, such as the estimated time of arrival, the license plate number, and the number of pallets. It is also possible to provide additional information such as a driver's mobile phone number. The program automatically generates the time slot in such a way that a driver does not have to wait too long, but also the unloading points are not jammed with traffic. (Majer 2019; Raz 2019.)

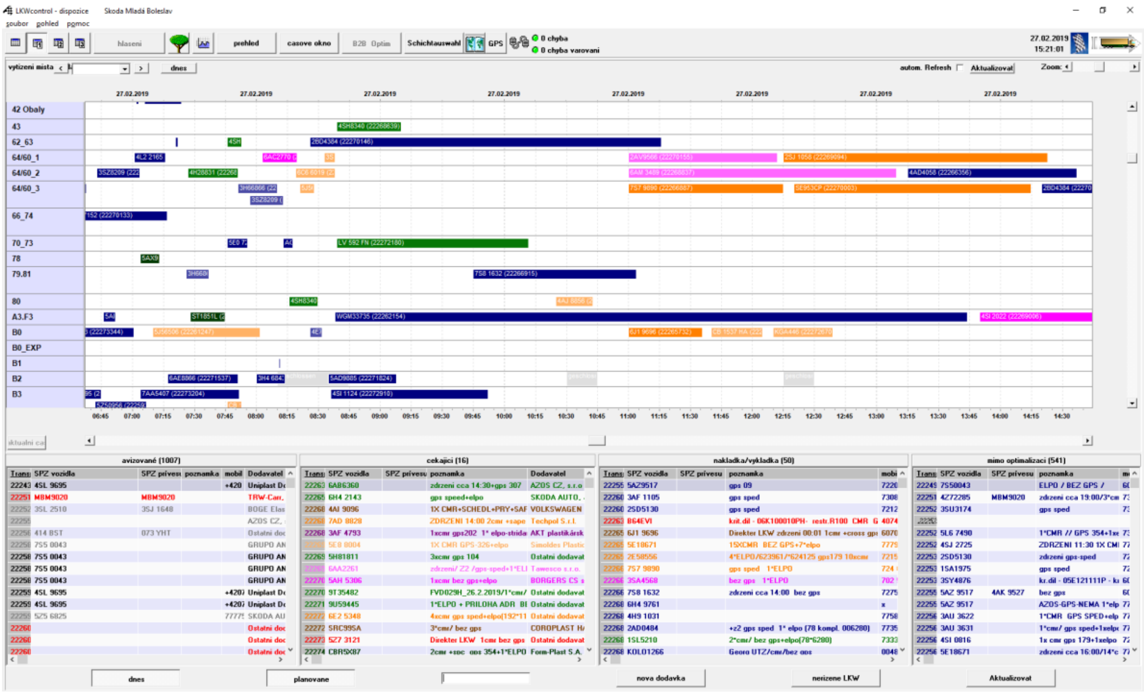

Figure 9 Overview of time slots (screen capture from the LKWcontrol-software).

It is possible to find information with the truck license plate number from LKWcontrol, but it is available only if the forwarder has booked the time slot. Different steps of the vehicle can be seen from the software like whether the registration has been finished or unloading has started. The plate number and all other information are removed from the system when the unloading is completed. (Raz 2019.)

5.2 Critical parts monitoring policy

The following text is divided into two parts, the first of which tells about the *people* who monitor the critical parts. The latter chapter describes *tools* that can be used for solving the dilemmas. There are some job titles which do not have unambiguous English translations, so the titles used in this text are versions that have become established within the PLD/1 department.

5.2.1 Parties of operation

The first link in the chain of the critical parts monitoring in the ŠKODA AUTO a.s. is a person called “disponent”. There are 66 disponents and each of them is responsible for over 550 items. The daily routines of disponent include the identification of critical parts and filling the “list of critical parts” based on this information. In practice, this means that they check the inventory levels from the inventory management systems, and if a part is below the alarm threshold, it is found critical and added to the list. Each person does not make their own list, because disponents are divided into seven teams depending on product groups and every team produces one list. Disponents are using a table of delivery times from different countries (Table 2) to determine the criticality. There are two options for delivery time, depending on the type of transport, and times are indicated in days. (Majer 2019.)

Table 2 Delivery times from different countries (adapted from Nouzová zásoba v okamžiku dodání, [Ref. 10 January 2019]).

State ↓ / Type of transport →	**Direct transport**	**Collection transport**
Czech Republic	1,5	1,8
Germany, Hungary, Poland, Slovakia, Austria	2	2,5
Belgium, France, Italy, Netherlands, Slovenia, Switzerland	2,5	3
Great Britain, Portugal, Spain	3	4
Romania, Croatia, Bulgaria, Estonia, Ireland, Luxemburg, Bosnia, Monaco, Serbia, Sweden, Ukraine	4	5
Turkey, Morocco, United Arab Emirates	10	10
Oversea (China, Korea, Mexico, Argentina…)	No direct transport	20

To illustrate the practice with a hypothetical example: a German supplier is dispatching parts straight to the ŠKODA AUTO a.s. from their company, and daily consumption of these parts is 1000 pieces. As shown in Table 2, the delivery time for transport is two days in this situation (Germany, direct transport). These factors are multiplied together, and the result indicates that the alarm limit is 2000 pieces for this part. In the same way, the disponents go through every product under their responsibility. (Majer 2019.)

Next, “disposition dispatchers” come into the picture, working tirelessly around the clock in three shifts. They combine the lists made by the disponents into one file, considering the cases that have not been completed during the previous day. This file is hereinafter referred to as the “*table* of critical parts” to differentiate it from the *list* of critical parts. The critical parts table is shared with other departments for information and used as a worklist for monitoring critical parts. Disposition dispatchers are also watching the production coverage, receiving information about production problems and solving the problems caused by lack of parts. (Majer 2019.)

Further, there are “transport officers”, who are mostly monitoring deliveries and communicating with forwarders and truck drivers. Their duty is to find out information about delayed deliveries, as well as lost, damaged, or not delivered shipments. Together with disposition dispatchers, they ensure that the production can proceed as planned. The PLD/1 team has a total of three transport officers, four disposition dispatchers, and their coordinator. (Majer 2019.) For solving different situations, there are several tools available that will be introduced in the next chapter.

5.2.2 Methods and measures to be used

In principle, some of the duties are on the responsibility of the disposition dispatchers and some of the transport officers. Since this thesis concerns the work of both of them, all the measures are discussed together in this text.

As stated in chapter 5.1, the orders are already made a long time before the case comes to the PLD/1 department. This means that the delivery should be on the way, and the easiest way to solve the situation is somehow expedite its arrival. Supposing that the license plate number is available in the inventory management system, one can check whether the time slot is booked for the truck in LKWcontrol. If so, and the schedule is appropriate for the production coverage, it may not be necessary to do anything. Information is not always found, especially in the case of collected transport, and then there is usually no choice but call the forwarder and ask. Sometimes the forwarder needs to be hurried up or instructed to take right measures. If the truck is arriving but the need for parts is very critical, the PLD/1 department can give a status *Engpass* for it via LKWcontrol, which indicates to the gatekeeper that this truck must be directed to the fast line to unloading. (Majer 2019.)

If the original shipment is not coming on time, one tool is to organize special transport. The transport can be arranged either directly from the supplier, from the cross-docking center, or from anywhere where the products presently are. The PLD/1 department looks for a suitable company among the contract forwarders, or on the free market, and the cost is charged from the company which is responsible for the delay. (Majer 2019; Raz 2019.)

Parts can also be borrowed from other locations. It naturally means that the same amount must be returned later, but it is not a problem when the most important thing is to make the production run smoothly at the moment. All parties ensure their own operations first, but if there are any extra parts available, then the borrowing is possible. ŠKODA AUTO a.s. has three factories in the Czech Republic (Mladá Boleslav, Kvasiny, and Vrchlabí), among which it is fairly uncomplicated to make transfers. The identical components may also be used in other Volkswagen Group cars. The inventory management system shows which factories are using the same parts and to whom the loan request can be addressed. In addition to factories, items can also be borrowed from Škoda Parts Centrum which mainly supplies spare parts to car repair shops. (Majer 2019.)

From the inventory management system, it is possible to see only the amount of parts in the warehouse, but not how much has already been collected into the workstations. Therefore, the actual production coverage time is longer than it seems to be according to the inventory level. In a tight situation, when the exact coverage time must be found, the PLD/1 department calls the production line and asks to make an extra inventory there. (Majer 2019.)

If the parts are completely running out, there are a few points on the production line (e.g. after the welding plant and after the paint shop) where cars can be taken off the line. Only models, which for there are no parts enough will be removed, so production only slows down slightly but does not stop completely. (Majer 2019.)

6 CONDUCTING THE RESEARCH

After wading through the theoretical part and the description of the present condition, the reader may still remember the main research problem: *how to reduce the need to contact someone to get information?* To answer this question, it is required to know how often contacting is necessary, what the reasons, and who the recipients are.

Therefore, a survey of occurred phone calls and emails was conducted in the PLD/1 department. After that, the causal connections behind the cases were investigated through individual interviews. The following chapter presents the arrangements, after which the reliability of the results is assessed and ethical issues are discussed in the second part.

6.1 Research design

A systematic observation was selected as the data collection method for the survey, which was the quantitative part of the research. In this context, systematic means that only the events (calls and emails) related to the research problem being investigated, were recorded. Any other information was unnecessary, such as, for example, cases where someone has personally arrived at the office to ask a question.

An observation table (Appendix 1) was created to collect the observations. Although it is not a questionnaire, the same principles as forming questions (see chapter 4.3) could be applied in this case: the options had to be sufficiently clear and precise. It was crucial that the staff of PLD/1 department understood the questions correctly as they made the actual observations and filled in the table. Therefore, to ensure its relevance, the table was developed in collaboration with the staff. It was also pretested by scrutinizing it with two employees. Moreover, some free space was left for cases that could not be considered in advance.

The first row in the observation table lists the possible reasons to contact someone and the first column includes potential recipients. The following recipients have already appeared in the previous text (5.1 and 5.2.1): disponent, supplier, and forwarder. From other options, the truck driver refers to a person working for the forwarder, and the dispatcher of the gate is an employee who works at the gate of the ŠKODA factory receiving truck drivers. The formatting of the table took into account the presumption that most of the contacts will be with the forwarders, so more space was left for their notes.

In addition to prepared alternatives, the research revealed two recipients more. The dispatcher of production is a person who oversees the operation of the production line. The external warehouse is a warehouse owned by ŠKODA AUTO a.s., located outside the Mladá Boleslav factory area. It mainly receives trucks that would otherwise have many separate unloading points at the factory and sends parts in smaller units to the internal warehouses.

In the table (Appendix 1), the first reason-column was for a case, when the truck license plate number was missing from the list of critical parts, and it was neither available from the inventory management system. The next column was necessary when the forwarder has not booked the time slot for unloading. The delivery note number should be given by the disponent, but if it was forgotten or there were some mistakes in it, the third column was there for that. The next two columns were needed when a truck arrived, but some of the load was missing or there were shortcomings in the shipment documentation.

Checking loading time refers to the moment when the goods were loaded onto the truck from the supplier's warehouse, and the arrival time means the estimated time when the truck would be at the ŠKODA factory. Sometimes the PLD/1 department needs to know where the truck is going between these times, so there was a column for that. The observation table also included space for the situation, in which one receives contradictory information and needs to verify what is true. Last option was for the case when one wanted to know in which stage of the supply chain the parts were. The research revealed two reasons more: the first of which an additional calculation of parts had to be arranged on the production line and the second when a price for the special transport was inquired.

A good way to make notes with differently directed arrow symbols was found in pre-testing, but there is no instance available because the completed forms were not included in the appendices. However, the upward arrow indicated contacting outwards from the PLD/1 department, and the downward arrow meant the opposite situation. Valli reminds in his book (2015, 4.0) that entering the answers to the statistical program should be able to do easily. The use of arrow symbols is a quick and visual way to mark the findings, but compiling answers to analysis is slow and involves the risk of making mistakes. Due to the small size of the target group it was noticed that this manner still provides more benefits than problems, so it was decided to introduce.

Two days were chosen for the duration of the observation because it was estimated to be long enough to provide a reliable number of observations. The purpose was to find the quantitative differences between different cases; which things had happened more often than others. Because the employees knew from experience that the usual events were repeated regularly every day, such a relatively short observation time was found to be enough. On the other hand, as the employees filled in the form themselves, the filling would have not be accurate and the daily routines would have be too disturbed if the time had been longer.

The survey was followed by qualitative interviews, whose purpose was to find out why the information was not available in the electronic systems, but a call or an email was required. The material of the qualitative part was collected from two employees of the PLD/1 department and they were asked to answer two questions:

1. *Was there a place for the information where it should have been, or whether the filling had been forgotten?* This was to identify whether there was a need to focus on developing a system or retraining a person.

2. *Is it easy for the recipient to find the information when asked?* By this it was wanted to find out whether the recipient also needs the same data for his or her own activities, in which case it may already be available in digital form.

6.2 The reliability of the research and ethical reflection

Seven out of the eight employees of the department finally participated in making observations, resulting in a response rate of 87,5%. According to Valli (2015, 4.0), sixty percent can mainly be considered as an adequate response rate for the success of the survey.

Another term related to the sufficiency of data is saturation, which means that the new answers no longer give new information (Tuomi & Sarajärvi 2018, 3.4.1). When looking at the combined and rearranged survey results (Appendix 3), it can be calculated that the difference between two consecutive recipients is maximally 135 observations (from the forwarder to the disponent) and the average of differences is 30 cases. Similarly, the average difference between the consecutive reasons is 11 and the maximum is 79 cases (between the arrival time and the location of the truck).

So, it is not just a few observations' difference, where it can be assumed that if the research had been continued, the order would not have changed, at least not among the leading positions, but the gap between the cases would have increased. In view of these figures, it can be stated that there is enough material and it represents the real situation.

The reliability of the material is also affected by the triangulation, and depending on the interpretation, this thesis uses at least two types of it. There is investigator triangulation in the sense that in the quantitative part the observations are made by eight different employees. It provides a comprehensive overview of the whole activity when people work even in different shifts at different times of the day. Methodological triangulation appears because the research includes both the quantitative and the qualitative approach.

The third option, data triangulation, is slightly questionable in this case. In principle, there were people in three different positions (the disposition dispatchers, the transport officers, the coordinator) but they were on the same side while working towards the same goal. For proper data triangulation, research should also be done within the groups *outside* the PLD/1 department that communicate with the department (cf. Tuomi & Sarajärvi 2018, 6.5). Therefore, it seems the best to stick to a more rigorous interpretation and state that two triangulation methods were used.

Further, it is possible to assess the validity of the research, which means that the study measures what it was intended to measure (Vilkka 2015, 7.0). The validity suffers if the respondents misunderstand the questions or the purpose of the research, and therefore the topic was contemplated in advance (see chapter 6.1, second paragraph). Nevertheless, the qualitative part of the research showed that there were three response options in the form whose differences were not unambiguous. Vilkka (2015, 7.0) believes that the impact of random errors may not be high, but it is important to detect and acknowledge them. Therefore, this is also done in this thesis (see chapter 7.2). On this basis, it can also be stated that the material is valid and has been collected appropriately.

The ethical reflection of the research subject should include a clear definition of why the research is executed and under whose terms (Tuomi & Sarajärvi 2018, 5.4.2). This research was done to simplify the work of the PLD/1 department, but the intention was to eliminate unnecessary work steps and not just transfer work to others. Further, according to Tuomi & Sarajärvi (2018, 5.4.4), the researcher must ensure that the rights of the participants are not violated and that they know the purpose of the study. The nature of this research is such that there is no risk to put respondents in a bad light since it covers only the general content of work and not the personal measures. Either way, the rights are guaranteed by the facts, that answering was voluntary, participants got clear guidance on the purpose of the study, and the answers cannot be combined with individuals.

7 RESULTS

This chapter analyzes the data generated by the research and creates a possible solution to the research problem. The two first chapters examine the results of the quantitative and qualitative parts and raise important findings. The third chapter lists individual ways to influence these points, and evaluates the pros and cons of each action. Based on this list, the final, reasoned vision of the solution, its effects, and the steps needed to implement it are presented in the last chapter.

7.1 Findings from the quantitative part

The research distinguishes the calls and messages, as well as their directions, but for the sake of clarity, this chapter first discusses the sum of all cases per recipient. When looking the survey results (Appendices 2 and 3), one can notice that there are 7 types of recipients and a total of 12 reasons. Of course, all possible cases with a different reason and a different recipient, altogether 84 variations, did not materialize, but 34 of them were detected more or less often. It was necessary to find the most frequent observations to focus on solving them.

If looking for the five most common reasons, it turns out that most of the observations, 119 pieces, have come from a truck arrival time query. The second most (40 times) inquired thing was the location of the truck and in the third place there was the checking of the loading time (32 times). The current location of goods was the fourth most traced (31 times). The fifth place was shared by situations when a truck had arrived either without products or documents (22 times of each).

There were so few recipients that it was advisable to select only three most often appeared cases for a review. Clearly, most often the recipient was the forwarder (182 times). The second one was the disponent (47 times) and the third was the truck driver (33 times).

The third way to interpret the results is to look for the most recurring individual cases. Most of the observations (95 pieces) have come from a situation when information about the arrival time of the truck was needed from the forwarder. It is followed by asking about the location of goods (30 times) and the location of the truck (24 times). Also in these cases, the forwarder has been the recipient. The fourth most common event was the discussion of missing documents with an external warehouse (16 times) and the fifth was the truck location inquiry from its driver (13 times).

When all these cases are summarized, it is possible to name ten most important issues to develop (Table 3). The matters are not sorted by importance but grouped by reasons, and the order is otherwise coincidental.

Table 3 Most important issues to develop

Reason	**Recipient**	**Direction**
Arrival time	Forwarder	OUT
Arrival time	Truck driver	OUT
Arrival time	Disponent	IN
The location of the truck	Forwarder	OUT
The location of the truck	Truck driver	OUT
Loading time	Disponent	OUT
Loading time	Truck driver	OUT
The location of goods	Forwarder	OUT
Missing goods or documents	External warehouse	IN
Missing license plate number	Disponent	OUT

7.2 Findings from the qualitative part

When the backgrounds of the cases presented in Table 3 were clarified qualitatively, some significant findings were made. To begin with, the cases in which the forwarder was the recipient (the arrival time, the location of the truck, the location of goods) were similar. When one of them was discovered, the answer to the other two often became evident simultaneously. There is no system between the PLD/1 department and the forwarder to share this information and the forwarders' practices are differing greatly. Some companies have GPS monitoring for vehicles and accurate electronic shipment tracking, but some have hardly any control.

Similarly, there is no system between the truck drivers and the PLD/1 department, and all companies do not give the drivers' phone numbers even when asked. If it is possible to contact the driver, usually the information on the time of loading or arrival and the current location is readily available. The driver surely knows his or her route, driving and rest times, and traffic conditions. For this reason, the driver is usually able to give the best and most reliable information about the shipment.

If the supplier has filled the master data correctly to the inventory management system, the disponent can find the loading time and write it to the list of critical parts. Nevertheless, every disponent does not write the information even if it is available. The system exists, so if the information is missing it is due to forgetting or other human error. The situation in which the disponent has been asked for a missing license plate number is similar: the existing system includes manual steps, which makes it possible for a person to make a mistake. These two cases can, therefore, be considered not important (see Figure 10).

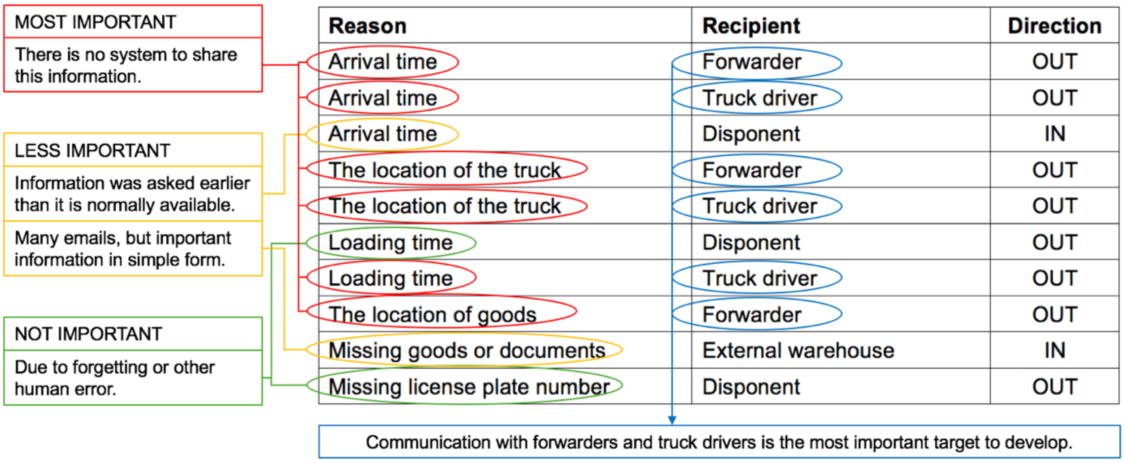

Figure 10 Most important targets to develop

In addition, as shown in Table 3, there were two frequent cases when information was asked from the PLD/1 department (direction: IN). In the first one, the disponent asked for the arrival time of goods. This is a piece of information that will normally be found in the table of critical parts, but in these situations, the information was desired before the table was ready to be shared. The information is normally available after the PLD/1 department has done its work and found out the location and the schedule of the shipment.

Another common inward-directed case was when an external warehouse contacted when the goods or documents were missing. This stands out from other cases because they are sending a form with the observations of received shipments by email.

The purpose of the message is to give work to the PLD/1 department rather than ask for information so that this case can be seen as irrelevant for the thesis. Although this mode of operation generates many emails, it is a simple way to convey the information that the PLD/1 department needs to find out the fate of missing things. Consequently, neither of these cases seems to require a structural solution, so they can be said to be less important (see Figure 10).

As discussed at the beginning of this chapter, there is no system available to transfer information between ŠKODA and the forwarder or the truck driver. Therefore, it can be said that communication with them is the most important target to be developed, and ways to resolve this will be sought next.

7.3 List of alternatives for the solution

Possible alternatives and their pros and cons are discussed here in the form of a list. The actual vision of the solution is based on this list and presented in the next chapter 7.4. Defining roughly, solutions can be divided into three parts as follows:

- No changes to the systems, only developing instructions.

  + An inexpensive and simple option.

  - Existing systems do not have the necessary features ready.

- The development of existing systems.

  + A mid-range option that already has the basis.

  - Existing structures may limit the development of the programs.

- Completely new system.

  + It can be tailored right from the beginning.

  - The most expensive option. Using the system may require some measures that otherwise would not be necessary.

If considering mere features, measures, or means, irrespective of whether they were implemented in the new or old system, the following list can be formed:

- Marking all the stages of a shipment to the system. (Advantages: traceability. Problems: marking should not cause an unnecessary work phase for the forwarder.)

- Automatic arrival time evaluation based on realized stages. (Advantages: no need for manual measures. Problems: how to consider traffic conditions and driver rest times.)

- Information on whether the transport is planned to be direct or via cross-docking. (Advantages: more predictable timetables. Problems: someone needs to enter the data to the system.)

- Positioning system on pallets. (Advantages: timely and accurate information. Problems: the locator consumes electrical energy and is difficult to load, combining pallets with shipment information is laborious.)

- Positioning system on trucks. (Advantages: timely and accurate information, some companies already have such a system for their own needs. Problems: sharing continuous location is problematic in terms of data protection, does not reveal whether the truck has the right products or not.)

- Pallet tracking with a bar code or a QR code. (Advantages: barcodes already exist on the pallet labels, inexpensive. Problems: reading the codes requires handwork.)

- Tracking the entire shipment with a bar code or a QR code. (Advantages: the code is easy to print on the delivery documents, the statuses of every pallet are logged all at once, some forwarders already have tracking systems and code readers for their own needs. Problems: not everyone has the readers, how to share information from the forwarders' own systems.)

- Truck drivers and warehouse workers have the necessary software on a mobile phone or a tablet. (Advantages: no need for specific data terminal equipment, notifications of forgotten measures and communication with the driver are available, possibility to share geographical data. Problems: continuous location sharing requires extensive data protection measures.)

- Visual tracking view of the shipment stages. (Advantages: the status of the shipment is seen at a glance, it is possible to estimate the success of the schedule based on time stamps. Problems: how to collect information about the stages.)

7.4 Choice and reasoning of the solution

This chapter is divided into three parts: the vision, the effects of change, and the necessary steps to achieve the vision. Decision-making was guided by one underlying idea: it is not worth developing your activities at the expense of the partners. The justification for this idea can be found in the supply chain management theory, for example in chapter 3.5.2. The principle was that whatever the solution will be, it must also bring benefits for the forwarder.

Chapter 7.4.1 only refers to a goal situation and the differences regarding the current state are not emphasized. The reader can compare the text with chapter 5 to get an impression of the changes. After that, chapter 7.4.2 evaluates the effects of the vision and the last part, chapter 7.4.3 lists the steps needed to achieve it.

7.4.1 The vision

Essentially, the vision is about developing an existing system. The platform is above-mentioned Discovery-software, which is convenient because most of the forwarders already have the access rights and they use the system regularly. For those forwarders who are not using this software yet, it would be effortless to adopt it as there is a comprehensive user manual available. This vision underlines the traceability of the deliveries which is achievable by logging all stages of transportation into the system. For this purpose, a new tab for a visual tracking view (Figure 11) is created to the software. Next, the vision will be presented with an example of an imaginary transport between Belgium and Czech. In this case, a forwarder's office is in Bryssel and a supplier is located in Antwerpen. Additionally, the forwarder uses a cross-docking center in Kassel and products are delivered to the ŠKODA factory in Mladá Boleslav.

Delivery note number: 53597769 **Estimated time of arrival:** 3.2.2019, 14:20, (Mladá Boleslav)

Time slot: 16:30

Date	**Time**	**Status**	**Location**
3.2.2019	08:32	Items received from cross-docking center	Kassel
2.2.2019	20:21	Items unloaded to cross-docking center	Kassel
2.2.2019	15:05	Items received from supplier	Antwerpen
2.2.2019	15:00	Delivery note printed	Antwerpen
1.2.2019	12:02	Loading list printed	Bryssel

Figure 11 Preliminary drawing of the visual tracking view.

Once the supplier has made a shipping order (through Discovery), the forwarder will print a loading list from the system (see Figure 12, left side). Printing will require selection (tick to the box) whether the transport is planned to be direct or go through a cross-docking center. More accurate prediction of arrival time is available in that way, while one clicking is not too laborious. It is assumed that the forwarder knows how it is going to handle the delivery when it is sending a truck to the supplier.

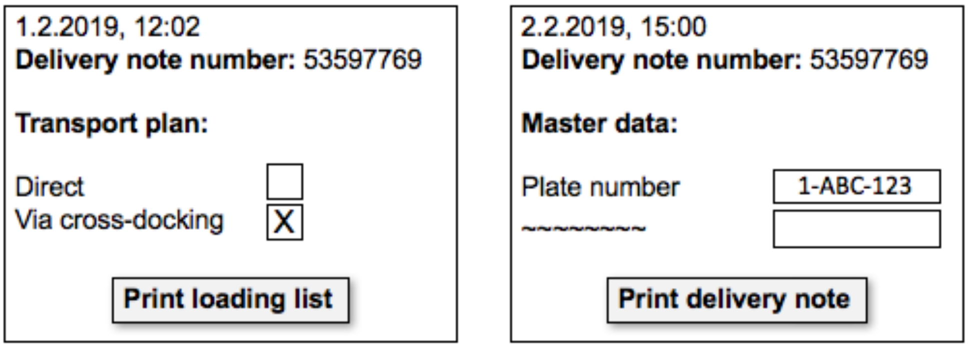

Figure 12 Preliminary drawing of the printing views

The loading list will contain a QR code (Quick Response Code, a two-dimensional barcode) that the supplier reads, which allows the correct pallets to be found in the warehouse. The supplier will write the master data (see Figure 12, right side) to Discovery and print the delivery note. In this system, printing the delivery notes does not create the status *loaded* as in the past, but *delivery note printed*. The blank box in Figure 12 refers to the other information listed in chapter 5.1, but the truck license plate number is the most important for tracking.

The delivery note will bear the same QR code, so there is no significance which document is used for logging from then on. In order to read the codes, a terminal is needed, which in this case will be a smartphone with a mobile application. Creating the application will cause costs, but it is less expensive than a dedicated device, and easily customizable to meet changing needs. If a forwarder already has a logging system for its own use, there is no need to use both in parallel, because the necessary information can be transferred from the forwarders system to Discovery.

Continuing the example (assuming that this forwarder did not have its own system) the next step is to acknowledge the goods as received by the application. The truck driver will read the QR code from the document and select the status *items received from the supplier* (Figure 13, left side). Besides having a reader of the QR code, the application will also have a location data recorder, so the application will store the status, the time, and the current location to Discovery (as shown in Figure 11). If the driver makes the status later, even after leaving the supplier, the loading time information will not be distorted, as the geographical data tells where the truck was at the time of logging.

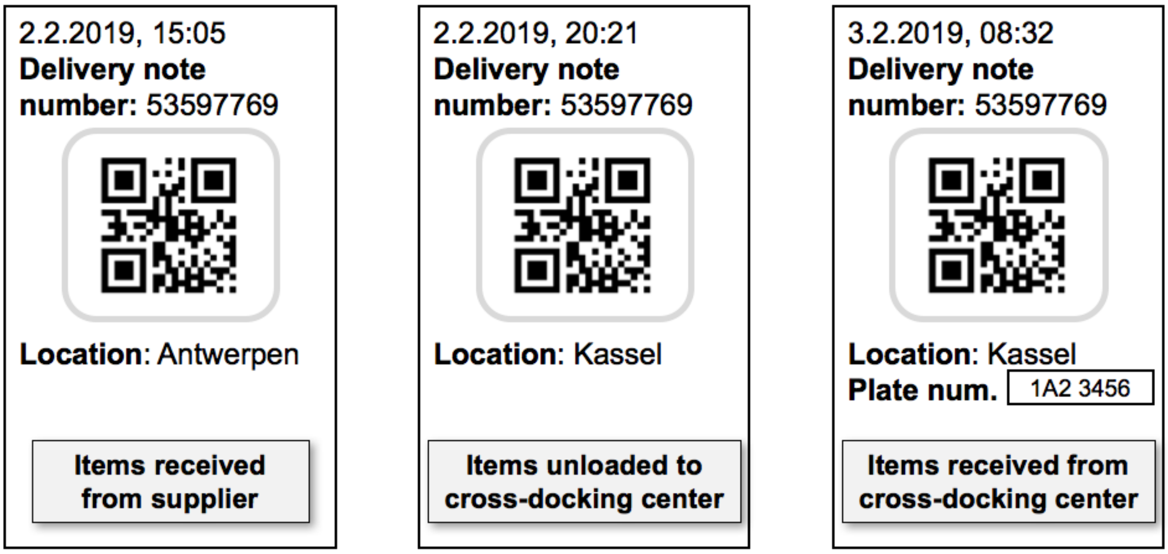

Figure 13 Preliminary drawing of the mobile application

If the transport passes through the cross-docking center, the QR code will be read at the time of unloading, and the status *items unloaded to the cross-docking center* will be saved (Figure 13, in the middle). Further, when pallets are loaded onto a new truck, the driver will read the code and select the status *items received from the cross-docking center*. At this point, the license plate number of the truck will also be filled to the application (see Figure 13, right side). The numbers will remain in the memory of application, so when the driver often drives the same truck it is not necessary to write the number always, but I can be selected from the list.

When an employee of PLD/1 department needs to know where the delivery is going, he or she will write the delivery note number to the visual tracking view and get a list of all the stages that have occurred so far (Figures 11 and 14). Also, the program will show the estimated arrival time. The time will be calculated by artificial intelligence based on the location information about the latest logged stage and historical transport times. Once the forwarder has booked the time slot in LKWcontrol, it will also be shown in the tracking view. Thus, it is easy to see if a too late time slot is given to the delivery in terms of its criticality. Clicking on a status mark provides more information about it, such as truck license plate number and user identification number of the person who made the entry (Figure 14). Clicking on the location opens a map view that can be used to check in more detail where the status was made.

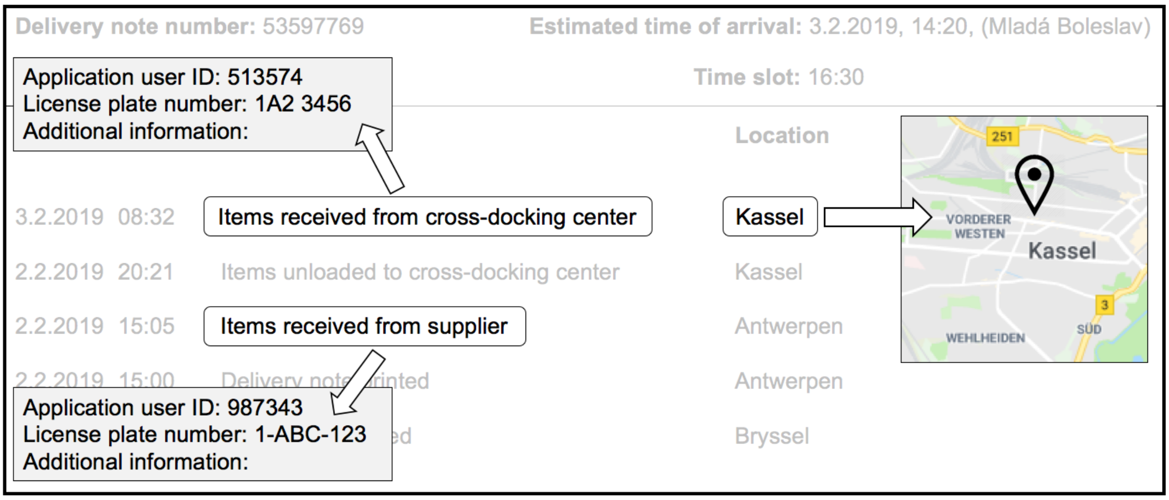

Figure 14 Preliminary drawing of the visual tracking view with additional information.

Although the system will provide this data, the employee of PLD/1 department must critically reflect on the estimated time of arrival and compare it with the production coverage time. Following the experience, he or she will decide whether it is necessary to verify the information from the forwarder or take other measures to ensure the production. It will also be possible to communicate directly with the truck driver through the system, for example, by sending notifications (see Figure 15).

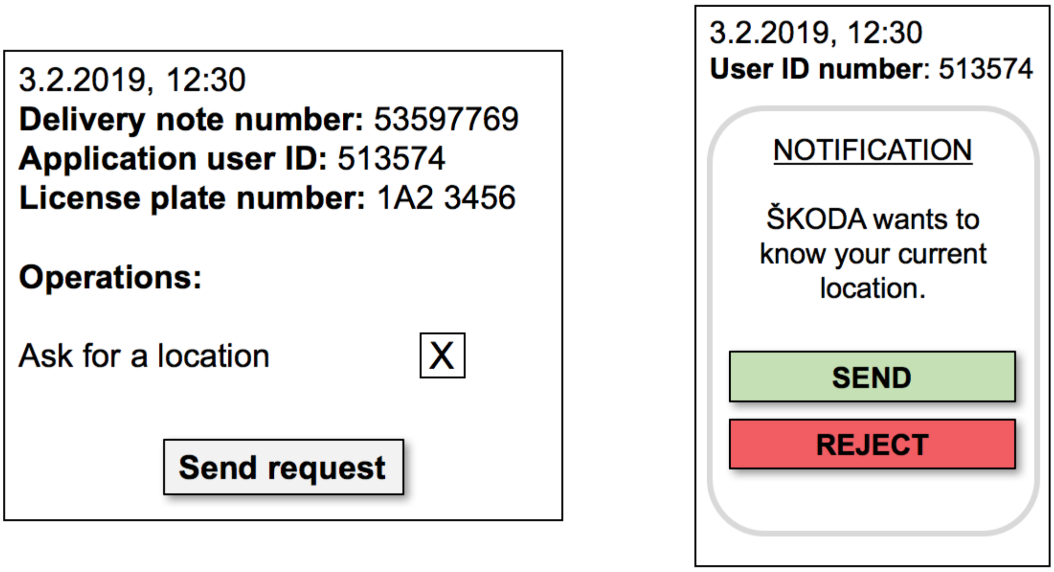

Figure 15 Preliminary drawing of additional operations

Lastly, a few words about data protection. According to the EU General Data Protection Regulation (GDPR), the location information must be considered as personal data. Data can be stored when the data subject has given consent to it and if the information is processed fairly and used only for the specific purposes for which they were collected. (EU 2016/679, Article 4(1), Article 5(1), Article 6(1)(a).) So there is no problem saving the location since the user of the application has allowed it. Sufficient action is if the permission is asked at first login and the user can accept it by clicking a specific button (EU 2016/679, Article 4(11), Text with EEA relevance(32)).

It is good to have a unique identification number (as shown in Figures 14 and 15) for each mobile application user to know who made the status if more information is needed. Also, a call feature can be created to the application and when separate applications are identified, it is possible to communicate between the application users with the ID number. However, the system does not need to store the *names* of users or *personal phone numbers*, so the data minimization referred to in Article 5(1)(c) of the GDPR is implemented. If it ever happens to be necessary to know the name, the forwarder can find out the information when asked.

7.4.2 Effects of change

According to Appendix 2, a total of 247 calls have occurred during the survey, of which the forwarder or the truck driver was at the other end 197 times (80% of the cases). Emails were never sent to or received from the driver, but this mode of communication was used with the forwarder 18 times, resulting in 25% of the total number of emails (71 pieces). If the vision would completely eliminate the need to contact a forwarder or driver, the total number of contacts in the PLD/1 department would fall by 215 pieces (68%), but such a total reduction is unlikely.

For the more detailed estimation, the first six reasons from the table (Appendix 2) can be examined more closely. These cases are such that an electronic system is available to share the information, so there should be no need for calls or emails. Nevertheless, the observation period revealed 31 contacts with the forwarder or the driver on these topics (see Figure 16).

REASON → RECIPIENT ↓	SUM ↓		Missing license plate number	There is no time slot for unloading	Delivery note number is wrong or missing	Missing documents (truck comes without documents)	Missing goods (truck comes without goods)	Checking loading time
Forwarder	3	Call IN		1	1	1		
	15	Call OUT	2	6			2	5
	1	Email IN		1				
	3	Email OUT					3	
Truck driver	2	Call IN		1				1
	7	Call OUT						7
		Email IN						
		Email OUT						
TOTAL	31	SUM →	2	9	1	1	5	13

Figure 16 Cases with the forwarder and the truck driver where the electronic systems exists (extract from the survey results).

Considering that the PLD/1 department monitors an average of 200 deliveries per day (Raz 2019), it can be assumed that if every case would need one call or email for each of these six reasons it would make a total of 1200 contacts. When only 31 contacts were needed due to existing electronic systems, it can be estimated that generally 97% of the cases are removed by the applications. It is just an estimate, because there is no data on the situation where these systems would not be in use.

The rest instances in Appendix 2 are such that an electronic system does not exist. Leaving aside the cases where the information from different sources was contradictory, there are three reasons left why the PLD/1 department have had to be in contact with the forwarder or the driver (the location of the truck, arrival time, the location of the goods). 173 observations of such cases were made during the study (see Figure 17).

REASON → RECIPIENT ↓	SUM ↓		Checking the location of the truck	Checking arrival time	Checking the location of the goods
Forwarder	18	Call IN	2	16	
	117	Call OUT	18	76	23
	4	Email IN	1	1	2
	10	Email OUT	3	2	5
Truck driver	1	Call IN		1	
	23	Call OUT	13	10	
		Email IN			
		Email OUT			
TOTAL	173	SUM →	37	106	30

Cases with the forwarder and the truck driver where the electronic systems do not exists	173
General assessment of the impact of an electronic system	-97 %
173 * 0,97 = 168	
Assessment of the impact of the vision	-168
All cases with all the recipients	318
318 - 168 = 150	
168 / 318 = 0,53	
Assessment of the impact of the vision	**-53 %**

Figure 17 Cases with the forwarder and the truck driver where the electronic systems do not exist (extract from the survey results) and the assessment of the impact of the vision.

If this vision reduces these cases also by 97%, it means that 168 pieces of these contacts (for only these three reasons) would be removed. Other cases are thought to remain unchanged, as the vision does not change their systems. As a result, the number of all calls and emails would fall from 318 to 150, which means *a 53% drop in the number of contacts*. The research has not traced the time spent on contacts, so the time savings cannot be estimated.

The solution will be also helpful for forwarders, as they benefit from the better traceability of deliveries. It reduces the risk of shipment delays and losses, which would cause costs. If the forwarder does not already do shipment tracking for their own needs, this vision will create a few more phases for them. The steps are still simple and quick to do, and most importantly, they are profitable. It is easy for the forwarder to start implementing these practices because they would be offered a ready-made system without expensive investments. If the forwarder has a tracking system previously, it will not need to use two parallel systems, but the necessary information can be transferred to Discovery via the appropriate interface.

It is worth considering whether the disponents should also have access to Discovery, that they could check the status of the delivery before entering it to the critical parts list. If the delivery is such a stage that it does not require special monitoring, it could be left without adding to the list. Thus, the PLD/1 department will receive fewer tracking requests.

7.4.3 Necessary steps to achieve the vision

Since the research was done only within the organization of ŠKODA AUTO a.s. the next important step in realizing the vision would be to get to know forwarders' practices better. One needs to study how widely the tracking systems are already in use and how willing the forwarders are to share the information outside of their company. The subject could be surveyed among all contract forwarders, for instance, as a thesis project. This is the first point in the timeline in Figure 18.

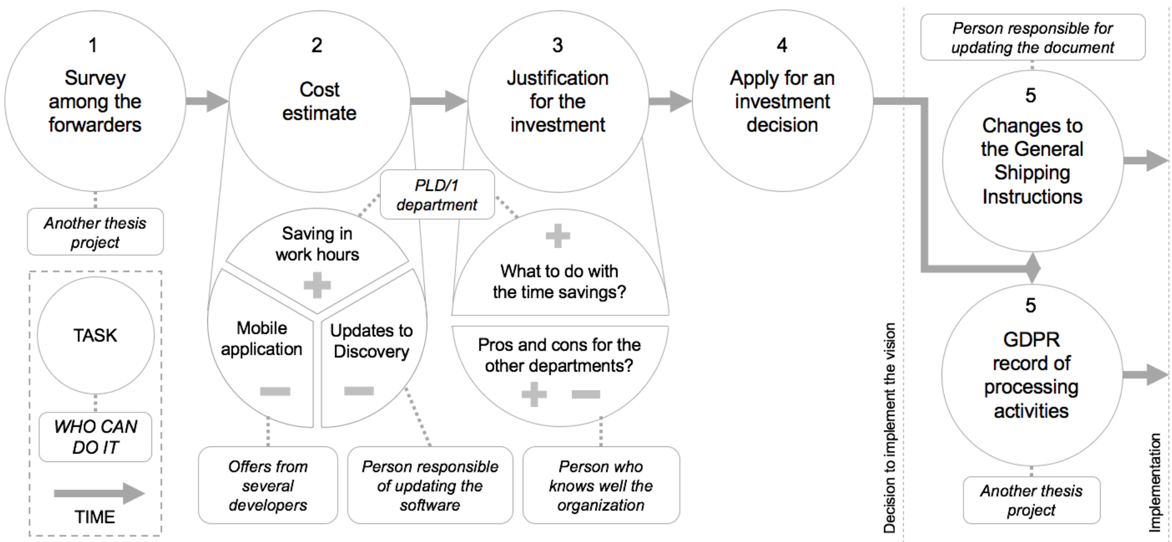

Figure 18 Necessary steps to achieve the vision

Implementing the vision calls for some investments, so the costs should be estimated more closely (second point in Figure 18). There are three important parts in the cost estimate. To begin with, an offer for creating a mobile application should be asked from a few different developers. The cost of changes to the Discovery-software must also be determined, and the people responsible for updating it will certainly be able to answer it. As this thesis provides the estimate for the decrease in the number of calls and emails (see chapter 7.4.2), saving in working hours can be assessed by measuring the time taken in individual cases.

The justification for the investment (third point, Figure 18) may need clarification of for what kind of productive activity these minutes could be used. The staff of the PLD/1 department can consider alternatives while assessing the amount of savings. There should also be a study of whether the vision is beneficial or harmful to the other departments of ŠKODA AUTO as well. This investigation would be best to do by a person with experience of the organization. After that, it is possible to apply for an investment decision (point 4).

Then, if a decision is made to implement the vision, there are two steps which can be done simultaneously (number 5 in Figure 18). The implementation requires changes to the General Shipping Instructions that are common to entire Volkswagen Group. The amendments can be done in cooperation with the person responsible for the shipping instructions.

In addition, if the data is stored to Discovery as previously mentioned (chapter 7.4.1) the software must be treated as a filing system (EU 2016/679, Article 4(1) and (6)). As discussed at the end of chapter 7.4.1, there are no obstacles to collecting information, but the record of processing activities is required (EU 2016/679, Article 30). It is not a particularly laborious task and well suited for example to a thesis subject or another student project.

8 CONCLUSIONS

The first part of conclusions draws together the content of the thesis. It is followed by the second part, which assesses the progress of the project, the achievement of the objects, and the overall success.

8.1 Content summary

The thesis originated from the need to reduce the number of calls and emails in the PLD/1 department of ŠKODA logistics, thus releasing labor capacity for other duties. The job description of the department principally includes monitoring the status of the incoming material and part deliveries. The idea of an electronic order tracking system that could solve the efficiency problem began to take shape at the early stages of the thesis project. Also, the commissioner emphasized the automatization of tasks and the digitalization of information transmission.

Some electronic platforms to transfer different pieces of information were already used in the department, but daily contacts with several recipients were still required for various reasons. Therefore, it was essential to investigate what kind of information is not currently available in digital form, and it was cleared up by conducting action research in the PLD/1 department. In the quantitative part of the study all phone calls and emails, their subjects, and recipients were recorded by the staff of the department for a period of two days. This was followed by the qualitative part, whose interviews provided more detailed information about why the information was not found on the electronic systems but a call or an email was required.

The observation period revealed that communication with forwarders and truck drivers is the most important target to be developed. They were repetitively asked for such information as the location of the goods, the location of the truck, and the estimated arrival time. The result was in line with the expectations, but this does not mean that the research would have been unnecessary. The survey scientifically confirmed the employees' perception and excluded the possibility of a false impression. An important part of the result is the sum of calls and emails that can be used to determine the effect of changes in the future if the measures to reduce them are decided to take. The employees of the PLD/1 department spoke altogether 247 times on the phone and sent or received information via email 71 times during the observation time. The thesis gives a reasoned estimate that 53% of these cases can be removed by developing the electronic systems.

The thesis presents a vision of the electronic order tracking system. The system would become part of the Discovery application, which is currently used for the communication between suppliers and forwarders. If the vision is implemented, the loading lists, which the truck driver needs to receive the right products from the supplier, and delivery notes, which the driver must take during transport, can be printed from the system. Both the documents will bear a QR code, which would be read with a completely new mobile application at different stages of transportation. The delivery status, including time, location, and description of the action, is stored to the system using the code. As a result, the realized stages of transportation, their details, and the time of arrival estimated by artificial intelligence would be visible at a glance without the need for a call or an email. If a forwarder has a similar system in place, it is not obligated to use two parallel systems, but the required data can be transferred to Discovery.

When getting familiar with the entire thesis, the reader will notice that the literature used as the source for the theory part, also supports this vision. For instance, larger inventories would decrease the risk of deliveries being critical thus reducing the workload of the PLD/1 department. However, increasing inventory levels inflict other problems, as presented in chapter 2.3 and 3.2, so it was not an option and other means were needed. Collecting information and sharing it transparently in the supply chain increases responsiveness and lays the foundations of correct decisions, as explained in chapter 3.5, thus it was an appropriate basis for the vision. Cost or task delegation to partners must be avoided as it does not reduce the cost of the final product as discussed in chapter 3.5.2, so the vision also considers this perspective as explained in chapter 7.4.2. At this stage, it is also convenient to point out how well the PLD/1 department has already planned the formal actions of resolving exceptional situations, which can be noticed by comparing chapters 2.4 and 5.2.2.

The next step on the way to implementing the vision would be to investigate, to what extent the forwarders have tracking systems in use and how willing they are to share the information. Offers for application development are needed to make a more detailed cost estimate for justifying an investment decision. Since this thesis principally determines the benefits of the PLD/1 department, also the effects of the change related to other departments should be examined. If the vision is decided to be executed, necessary changes to the VW Group General Shipping Instructions must be made and the GDPR record of processing activities must be created before introduction.

8.2 Evaluation of success

Unexpected difficulties in communication between the author and the commissioner caused confusion in the beginning of the thesis project, as the research problems could not be defined before the working period started at ŠKODA AUTO. Consequently, it was not possible to get to know the theory, nor to prepare the practical part in advance. After all, this did not cause any trouble, as it provided enough job to get acquainted with the day-to-day operation of the PLD/1 department until the definition was made. So, inefficiency was avoided and the work progressed effectively and according to the plan from then on. The author’s personal intermediate targets were sometimes overly optimistic and all of them were not reached, but the schedule agreed with the commissioner was kept.

The PLD/1 department would like to get to a situation in which the information needed to track deliveries could be found in computer programs. The objective of the thesis was to create a vision of a potential system, taking into account the steps needed to accomplish it. As both the vision and the steps can be found in this paper, it can be stated that the objective was achieved.

The work was a preliminary study and was not intended to create or implement any concrete system. Therefore, the success of the work cannot be assessed by calculating the actual decrease in the number of calls or some other similar thing. As the criteria for success, the commissioner had determined that the vision should be well argued and based on reliable research and comprehensive data analysis.

As to the demand for arguments, it was fulfilled because the vision was preceded by a comprehensive listing of the positive and negative aspects of the various measures and followed by considering the effects on both ŠKODA AUTO a.s. and the forwarders. The reliability of the study was indicated by the use of different triangulation methods, a high response rate, and saturation of responses. Processing the results revealed some random errors in the research arrangements, but they were acknowledged. Further, the data generated by the quantitative part of the research were analyzed by using three different approaches, and by combining them the most important things to develop were found. The issues were collected into a table and further explored through qualitative interviews.

In light of this reasoning, it is surely justified to say that the thesis met the criteria set for it and can be considered successful. After all, the author of the thesis would like to thank everyone who contributed to completing the work, especially the staff of the PLD/1 department.

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APPENDICES

APPENDIX 1 Observation table

REASON → RECIPIENT ↓		Missing license plate number	There is no time slot for unloading	Delivery note number is wrong or missing	Missing documents (truck comes without documents)	Missing goods (truck comes without goods)	Checking loading time	Checking the location of the truck	Checking arrival time	Different information from different sources	Checking the location of the goods	
Disponent	Call											
	Email											
Supplier	Call											
	Email											
Forwarder	Call											
	Email											
Truck driver	Call											
	Email											
Dispatcher of the gate	Call											
	Email											
	Call											
	Email											
	Call											
	Email											
	Call											
	Email											

APPENDIX 2 Survey results

REASON → RECIPIENT ↓	SUM ↓		Missing license plate number	There is no time slot for unloading	Delivery note number is wrong or missing	Missing documents (truck comes without documents)	Missing goods (truck comes without goods)	Checking loading time	Checking the location of the truck	Checking arrival time	Different information from different sources	Checking the location of the goods	Extra inventory	The price of special transport
Disponent	12	Call IN	3	3				3		1		1		1
	16	Call OUT	2		1	1	3	7			2			
	9	Email IN					1		2	5	1			
	10	Email OUT	3				2	1		2	2			
Supplier	5	Call IN		2				2	1					
	5	Call OUT		1				4						
	3	Email IN		3										
	2	Email OUT						2						
Forwarder	25	Call IN		1	1	1			2	16	4			
	139	Call OUT	2	6			2	5	18	76	7	23		
	5	Email IN		1					1	1		2		
	13	Email OUT					3		3	2		5		
Truck driver	3	Call IN		1				1		1				
	30	Call OUT						7	13	10				
		Email IN												
		Email OUT												
Dispatcher of the gate	7	Call IN			1	2				4				
	1	Call OUT								1				
	2	Email IN				2								
		Email OUT												
Dispatcher of production	2	Call IN											2	
	2	Call OUT											2	
		Email IN												
		Email OUT												
External warehouse		Call IN												
		Call OUT												
	27	Email IN				16	11							
		Email OUT												
TOTAL	318	SUM →	10	18	3	22	22	32	40	119	16	31	4	1

APPENDIX 3 Combined and rearranged survey results

REASON → **RECIPIENT ↓**	SUM ↓		Checking arrival time	Checking the location of the truck	Checking loading time	Checking the location of the goods	Missing documents (truck comes without documents)	Missing goods (truck comes without goods)	There is no time slot for unloading	Different information from different sources	Missing license plate number	Extra inventory	Delivery note number is wrong or missing	The price of special transport
Forwarder	182		95	24	5	30	1	5	8	11	2		1	
Disponent	47		8	2	11	1	1	6	3	5	8		1	1
Truck driver	33		11	13	8				1					
External warehouse	27						16	11						
Supplier	15			1	8				6					
Dispatcher of the gate	10		5	0	0	0	4	0	0	0	0		1	0
Dispatcher of production	4											4		
TOTAL	318	SUM →	119	40	32	31	22	22	18	16	10	4	3	1