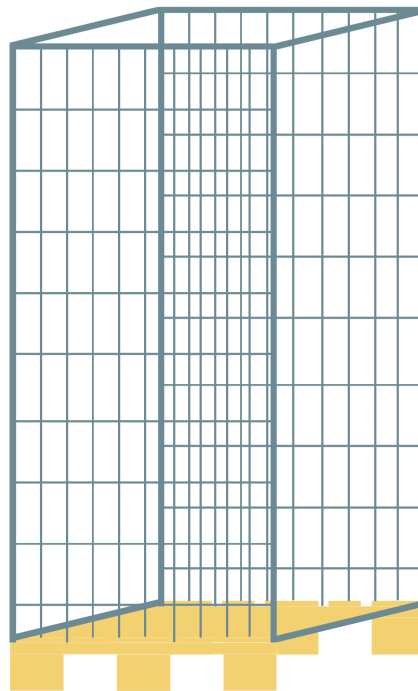




CHALMERS
UNIVERSITY OF TECHNOLOGY



A New Parcel-Cage Size and Tracking System: Effects on Transportation and Handling in a Logistics Company

LINNÉA WIDROTH

MASTER'S THESIS 2021

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Logistics Company**

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Department of Industrial and Materials Science
Division of Design and Human Factors
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2021

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Supervisor: Cecilia Berlin, Industrial and Materials Science
Anna Hagberg, DB Schenker
Examiner: Cecilia Berlin, Industrial and Materials Science

Master's Thesis 2021
Department of Industrial and Materials Science
Division of Design and Human Factors
Chalmers University of Technology
SE-412 96 Gothenburg
Telephone +46 31 772 1000

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Department of Industrial and Materials Science

Chalmers University of Technology

Abstract

When transporting parcels via trucks, optimizing the loading capacity (load factor) is important for economic and environmental reasons. Accessibility to parcel-cages in the parcel process is important for the delivery to run as efficiently as possible. The load factor of the truck is underutilized with the current parcel-cage, thus there is potential to increase the load factor with a different solution. One track in this master's thesis is to investigate how a new size of parcel-cage affects transport efficiency, ergonomics and time of handling cages. Another problem is the occurrence of long- and short-term shortages of cages in the process. A second track will therefore be to propose a new tracking system for the cages.

A triangulation of methods: literature studies, quantitative studies and qualitative studies; was used in this project. Interviews, observations and statistical data gathering and analysis were used to define the current state of transportation and handling of the parcel-cages. For the new solution, a literature study and quantitative study were carried out for the two tracks, defining and evaluating the optimal cage size and proposing a new tracking system. A comparison between the current state and the new solutions was conducted.

The optimal cage size was defined so that two cages could be stacked on top of each other, using bars inside the trucks. The new cage can potentially transport 39 % more parcels per pallet place than the current one, with regard to the average number of parcels transported in the different cages. The load factor in the truck increases by 44 % with the new cage. Packing parcels into cages was identified as the riskiest work task regarding physical ergonomics. The cages were divided into three zones depending on the lifting heights. The medium zone (from knee-level to shoulder height) is considered an acceptable lifting zone. The low and high zones are considered more ergonomically risky lifting heights. The study indicates that the new cage dimensions increase the number of acceptable lifts by 44 %, thanks to the difference in lifting heights. An evaluation of the physical loading for situations with different weight of parcel, posture and time was conducted. The combination of high-weight of parcels (>15 kg) with unsuitable lifting heights resulted in the riskiest situations. Since more cages are needed to transport the same volume of parcels, the time for handling the cages may increase by around 44 % for some work tasks.

Cage shortages can be reduced by providing knowledge of how the cages are transported and the inventory levels at the terminals, to facilitate empty cage transportation. The study suggests that the cages can become more available with a passive

UHF (Ultra high frequency) RFID (Radio-frequency identification) tracking system at cage-level.

The findings indicate that transport efficiency and physical ergonomics can be improved with the new cage size, while the time required for handling cages may increase. The new tracking system could reduce the handling time with a more automatic system and reduction of work tasks in production.

Keywords: Parcel handling, Cage handling, Parcel-cage, Transport efficiency, Physical ergonomics, Tracking system.

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Definitions

Arriving Terminal (also called Terminal 2, T2) - The last terminal the parcel arrives at in the parcel process. Responsible for sorting parcels within the area close to the terminal.

Cage app - An application used by terminal workers to, among other things, track how many parcel-cages sent daily between terminals.

Cage flag - A piece of paper that is put on each cage for terminal workers and truck drivers to easier see where the cage with parcel is heading.

Cage-lift - A lift enabling to rise and lower the parcel-cage. It is used in the work task of putting the parcels at the conveyor belt.

Carriage - Refers to a truck and/or trailer.

Conveyor belt - A belt transporting parcels from the where parcels are put on it to the outlines. Enables automatic division of parcels depending on their end destination.

Departing Terminal (also called Terminal 1, T1) - The first terminal the parcels comes to in the parcel process. Responsible for sorting incoming parcels to the different terminals throughout Sweden.

Foldable gate - A gate for the parcel-cage that is foldable in half. The gate can be put on halfway before it is closed the entire way.

Groupage - Goods transported together and handled at a terminal, generally with the help of forklifts. Goods generally weigh over 30 kg.

Haulage contract companies - Companies responsible for driving carriages with parcels and/or groupage between different terminals, customers or parcel agents.

Linehaul transportation - Transportation between terminals.

Non-foldable gate - A gate for the parcel-cage that is not foldable. Its size is from the bottom of the cage to the top.

OSHA - Abbreviation for Occupational Safety and Health Administration.

Outlines - The place where the sorting and packing of parcels occur. The end of the conveyor belt. An outline is specific to one or several terminals.

Parcel agent - A place where customers (normally private persons) can pick up or leave a parcel they have ordered or want to send away. Examples of parcel agents are grocery stores and kiosks.

Parcel-cage - A cage that transports parcels between terminals.

Parcel-cage process - The process concerning the parcel-cages in the linehaul transportation. Part of the parcel process.

Parcel flow - A parcel's process throughout the entire chain, from start to delivered.

Parcel process - The process the parcel undergoes from the start customer to the end customer. The parcel process generally starts when a parcel is collected at a pick-up point and transported to the first terminal in the process (Terminal 1). At the terminal, the parcel is sorted and transported to the correct Terminal 2, where it is sorted and transported to the correct distribution area.

Qlikview application - A statistical tool compiling data from different systems used in the company.

SWEA - Abbreviation for Swedish Work Environmental Authority.

Team leader - Person responsible for the daily production, either at departing or arriving terminal. First-line manager.

Terminal - A building where handling and sorting of parcels and groupage occurs for further transportation to the next destination.

Terminal manager - Highest manager at the terminal responsible for the operative work (parcel and groupage handling).

Terminal worker - A person working at the terminal in the parcel process (or groupage process) for the departing and arriving terminal.

Truck driver - A person driving the carriage between different places. Works for a haulage contract company.

Ugly parcels - Parcels that are handled differently than the normal parcels due to circumstances preventing them to be handled at the conveyor belt, e.g. too large parcel or unreadable bar-code.

1

Introduction

This chapter will provide an introduction to the reasons why this master's thesis is conducted and the purpose behind it. Firstly, necessary background information for the project will be provided followed by a problem definition. The aim and research questions will be presented and lastly, the project limitations will be given.

1.1 Background

The transportation sector includes shipment of people and products and is an important part of the economy and society we live in today. The efficient transportation of material and goods, the shipping industry, enables a competitive environment for global industries. Today, customers set higher and higher demands on transport solutions regarding climate and environmental aspects [1]. At the same time, the shipping companies need to be competitive in the market with competing prices and high dependability to secure customer satisfaction, thus high efficiency is vital. Another known fact is that the parcel delivery industry predicts an increasing volume trend for the years to come, largely due to strong growth in e-commerce, at about 17-28 % per year according to projection range given in the Parcel Shipping Index report [2]. Therefore, shipping companies need to keep up with developments and constantly push to become more productive and efficient in their work.

The German-owned company DB Schenker is a global company handling supply chain management and logistic solutions. The foundation of DB Schenker was established in 1872 by Gottfried Schenker when he founded Schenker & Co. In 2002 Deutsche Bahn combined two leading logistic companies, Stinnes AG and Schenker, to what today is known as DB Schenker. Their Swedish subsidiary Schenker AB consists of four main functions; Land, Air, Ocean, and Contract Logistics.

This master's thesis will be conducted within the main function Land transport and the subdivision Network & Linehaul. The subdivision is responsible for providing a competitive transportation network in terms of frequency, efficiency and lead time. Within Sweden there are 28 terminals in six different districts; West, South, East, Center, Stockholm and North, see Figure 1.1. Each terminal is responsible for the collection and distribution of products and goods within the area it is located and for transportation to other areas. Sweden, Denmark and Iceland are one cluster within DB Schenker with the head office in Gothenburg, where this thesis will be conducted.



Figure 1.1: DB Schenker’s 28 terminals in Sweden distributed in six districts. From [3]. Reproduced with permission.

Schenker provides two types of basic transport services called parcel and groupage. There is normally a difference in how different services are handled, however, the main difference between them is that a parcel weighs less than 30 kg and is shorter than 2 meters. Groupage can be anything that does not fit in the category of parcel. The handling of groupage is done by a forklift or manually, therefore, everything heavier than 30 kg needs to be put on a load carrier, e.g. a EUR-pallet. Further description and explanation in the report will concern the parcel process and its flows since this is within the scope of the project.

An important KPI (Key Performance Indicator) measured by Schenker in the parcel process is door-to-door delivery and dependability. To have high quality in deliveries and products is important for customers when it comes to trusting Schenker’s dependability. An example when dependability is important is in the business to business segment when delivery of a part or product can affect the entire production chain and could be a vital part of processing with operations. To enable improvement of the KPIs it is important to understand the parcel process and its existing steps.

1.1.1 Parcel process and use of parcel-cages

The first terminal handling a parcel in the parcel process is called the departing terminal or terminal 1 (T1). There are three ways a terminal can receive parcels, see Figure 1.2. The three ways are:

1. A truck picks up the parcel at a business or customer
2. A customer hands in the parcel to a parcel agent where it later is transported by a truck to the terminal
3. A customer hands in the parcel directly at the terminal

The terminal workers' task at the departing terminal is to sort the incoming parcels in parcel-cages (further called cages) depending on the next destination, to distribute them to the different terminals throughout Sweden. This work is happening at all terminals during the day/evening. The cages with the parcels are then transported by truck drivers in the linehaul transportation from the departing terminal to the arriving terminal or terminal 2 (T2) in the evening/night the same day. At the arriving terminal, the task of the terminal workers' is to sort the parcels to the correct distribution truck/car depending on where in the area close to the terminal its final destination is. The distribution of the parcels works in the same way as for collection, that is, one of the three ways described above. It is important to emphasize that a terminal is both a departing and an arriving terminal depending on what time of the day it is.

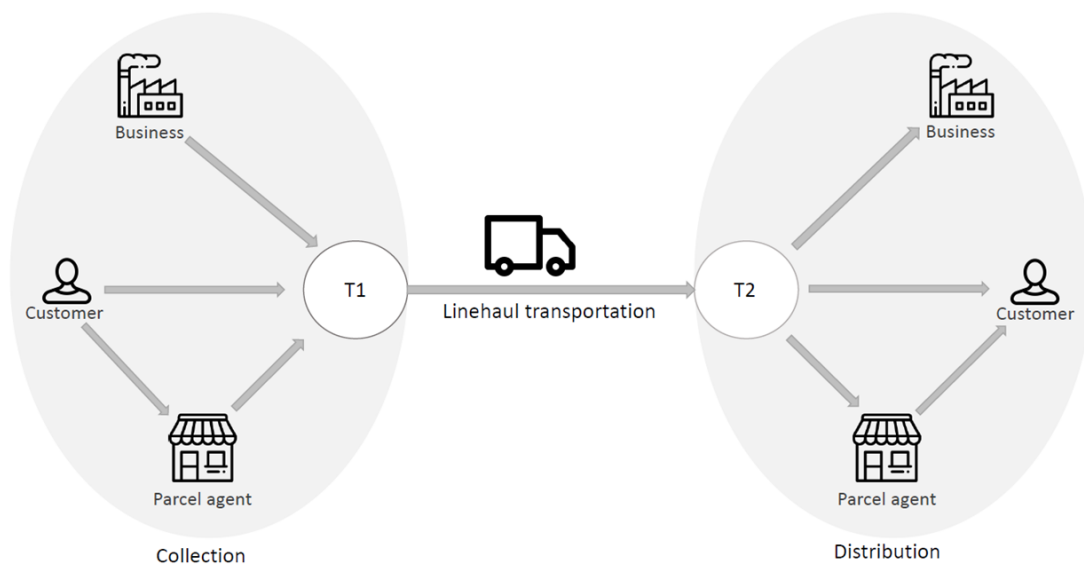


Figure 1.2: Different transportation ways a parcel can be transported.

The different transportation paths in the parcel process are shown in Figure 1.2.

Parcels are collected and distributed to/from the different terminals and transported in the linehaul transportation between terminals. The haulage contract companies (further called haulage companies) normally drive different types of distances (collection/distribution or linehaul transportation) and/or different types of products (cages with parcels or groupage). Depending on these variables the carriages used for different transportation can differ, for example regarding how many pallet places the carriage has and the inside dimensions of it.

The use of parcel-cages begins in the departing terminal with the sorting of parcels in the outlines for further transportation to other terminals in Sweden. In Figure 1.3 an example of a departing terminal layout is presented. When sorting of parcels to cages is done the cages are transported with the linehaul transport to the arriving terminal. The cages are then emptied at the parcel-cage lift, which enables the terminal worker to hoist the bottom of the cage for better ergonomic lifting, to get the parcel on the conveyor for further sorting.

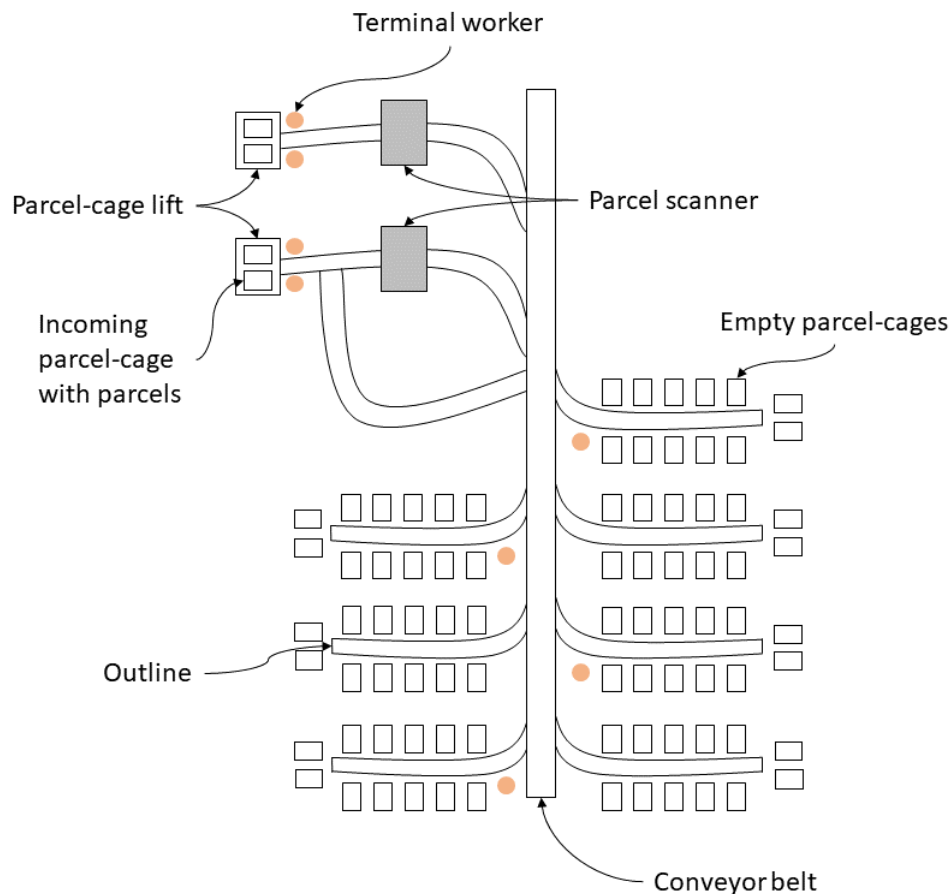


Figure 1.3: Example of a terminal layout.

The current parcel-cage consists of five parts that are removable to be able to stack and transport four cages into one, that is five parcel-cages in total. The cage consists

of a EUR-pallet in the bottom with two identical long sides and 2 short sides, called gates, that come in two different variants (a foldable and a non-foldable gate). In Figure 1.4 a parcel-cage with parcels inside can be seen.



Figure 1.4: Parcel-cage with parcels inside.

1.1.2 Current tracking systems of cages

1.1.2.1 Cage flag

On every cage, a "Burflagg" (in English: "Cage Flag") is put on to enable easier access to the information for truck drivers and terminal workers to know what final destination the cage has. The Cage flag is a piece of paper with the name of the final terminal written on it and a corresponding barcode. In Figure 1.5 the layout of a Cage flag with the final destination written on it and the position of the Cage flag on the back of the cage is shown respectively.



(a) Example of Cage flag layout.



(b) Cage flag position on the back of a cage.

Figure 1.5: Example of Cage flag layout and position on cage.

1.1.2.2 Cage app

A current way of tracking how many cages that are sent from every terminal each day is through the application "Burappen" (in English: "The Cage App"). The application provides a balance score for each terminal by comparing the sent number of cages for the terminal with the received number. The balance score is either positive if the terminal receives more cages than they send or negative if they have fewer cages than before at the end of the production day. In this application, terminal workers at each terminal scan the barcode on the Cage flag and record if the cage is going directly to the arriving terminal (final destination) or if it should go through the hub in Jönköping. The purpose of the hub is to collect cages (and other groupage) that for various reasons were not transported directly to their final terminal. The cages going to a specific final terminal are gathered and transported together, independently of which terminal sent the cages. With this possibility, the parcel can arrive at the final terminal the same day, thus avoiding an extra day until delivery.

1.1.2.3 Inventory

The current way of knowing how many empty cages that are in stock at a terminal is through inventories taken by the workers at the terminal every other week. The inventories rely on the workers at the terminals to count the number of long and short sides of the cage that are currently in stock at their terminal. They report this information to the head office in Gothenburg where all the data from the terminals are compiled into a document.

1.1.2.4 Qlikview application

The Qlikview application is a statistical tool compiling data from different systems used in the company. There are several different types of Qlikview applications, for example, one regarding groupage data and one regarding parcel data. Parcel-cage data is found in the groupage part of the Qlikview application. There are different contracts for the parcel-cages that enable different types of payment to the haulage company depending on different factors, for instance what type of distance they are transporting the cage. One example is when the parcel-cages are transported from the hub in Jönköping, another one is the transportation of empty cages. The information from the Qlikview application provides the data enabling haulage companies to get paid accordingly. The parcel data is found in the parcel part of the Qlikview application and provides information such as how many parcels are transported daily and what type of products the parcel is (domestic, foreign, parcel agent or logistical parcel).

1.2 Problem definition

Improving the load factor is important to reduce transportation costs in shipping and reduce emissions in transportation and thereby increase the efficiency. The current construction of the parcel-cage has a gap in height between itself and the inside height of the truck, which leads to unexploited capacity, see Figure 1.6. The load factor has, therefore, improvement potential since the capacity of the truck could be better utilized. A change in height of the parcel-cage will affect the transportation and handling of the cages. How the change will affect the terminal workers and truck drivers regarding these factors is yet unclear.



Figure 1.6: Cages loaded into a carriage with the gap in height between the cage's top and the ceiling of the carriage visible.

Another known problem is the shortage of parcel-cages in the system, both regarding a long-term perspective when cages disappear from the process and a short-term perspective when cages are not where they are needed for the production to run as smoothly as possible. Today the parcel-cages are owned by the head office in Gothenburg but used at all DB Schenker's terminals in Sweden. New purchases of cages are made by workers at the head office when the workers at the terminal report low levels of cages or when the inventory of cages indicates a low level. When the terminal needs empty cages fast, a worker at the terminal sends a request for empty cages via email to the other terminals. If a terminal has cages they can send, they will do it. This can also happen routinely between some terminals since some terminals always need cages (if they send more cages than they receive) and some have too many.

When parcel-cages are out of stock at a terminal the terminal workers sorting the parcels need to use back-up cages consisting of corrugated cardboard, see Figure 1.7. These back-up cages have other types of issues, like easily expanding to a wider width than the normal ones' when packing the parcels due to softer walls, enabling fewer cages to fit in the truck than under normal circumstances or a harder time to handle the cages. Shortages of the parcel-cages at the terminals might also affect customers negatively due to a lower number of parcels fitting in the truck since the capacity is lower for the corrugated cardboard cages or when using only a EUR-pallet. It could also lead to a higher number of damaged parcels leading to decreased quality in delivery. Using the back-up cages leads to higher costs since the back-up cage only can be used once and causes ineffective work for terminal workers and truck drivers due to the handling of the back-up cage. Therefore, a tracking system is of high value to track the parcel-cages for better control and reduced shortage of cages.



Figure 1.7: The corrugated cardboard cage used when shortage of parcel-cages occurs.

1.3 Aim

The main purpose of this master's thesis is to investigate how the transportation and handling would change if a new cage size and tracking system were implemented. An investigation will be conducted of how a new size for the parcel-cage, optimizing the load factor in the linehaul transportation, would affect the current parcel-cage process. The aim is also to understand what consequences the change will have for truck drivers and terminal workers regarding transportation and handling. The transportation considers the transport efficiency of parcels in the carriage and the handling considers the time it takes for handling a cage and the physical ergonomics in the process. A prerequisite for high productivity in the parcel process is the availability of parcel-cages when they are needed. A shortage of cages can have detrimental consequences for productivity and therefore an investigation regarding a tracking system for the parcel-cages will be conducted.

The investigation will concern the parcel-cages in the linehaul transportation process. This process starts at the departing terminal, T1, with a need for safe transportation of parcels in between terminals, and ends when the parcels have been transported safely to the arriving terminal, T2. The parcel-cages are used in other flows in the parcel production process, e.g. in the collection and distribution transport between customers and the terminals. However, separate investigations are ongoing to investigate if this can be done in other ways. The project will mainly focus on the parcels transported and sorted on the conveyor belt.

1.4 Research Questions

The purpose of this project has been condensed into two Research Questions, referred to from here-on as RQ1 and RQ2.

- **RQ1:** How will a new parcel-cage size, optimizing the linehaul transportation, affect transport efficiency, ergonomics and time required for handling cages?
- **RQ2:** What kind of tracking system could be implemented and used in the future to improve the accessibility and control and reduce shortage of parcel-cages in the process?

1.5 Project limitations

This master's thesis will be conducted at Schenker AB's head office in Gothenburg. The studies necessary for the project will only be conducted at two terminals in Sweden, Gothenburg and Växjö, due to the current outbreak of the new Coronavirus (Covid-19). The size of the terminals differs from each other, where Gothenburg is a large terminal and Växjö is a medium one, which provides variety. However, out of Sweden's 28 terminals, only two terminals can not be seen as a comprehensive

sample.

Other types of sorting processes than the sorting at the parcel conveyor belt will not be considered. For example, the handling of "ugly-parcels" (since they are handled differently due to circumstances preventing it to be handled on the parcel conveyor belt, e.g. the parcel is too large or if the barcode is unreadable). Another master's thesis is made focused on the ergonomics of handling ugly parcels at DB Schenker [4]. This means only parcels possible to transport at the conveyor belt will be considered in this project.

This master's thesis will only take effects on terminal workers and truck drivers into consideration.

The project is limited to investigating solutions which could be adapted to the current production layout.

2

Theory

The theory chapter compiles relevant theories and concepts in the study. These were used to support the methods chosen and provide a foundation for the project. It aims to enable understanding and provide the knowledge needed for interpreting the results.

2.1 Physical ergonomics

The International Ergonomics Association defines ergonomics to be:

“Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance [5].”

A holistic system approach of ergonomics looks into three main areas of ergonomics; physical, cognitive and organizational [5]. Since this project limits itself to the physical aspect, this will be further elaborated in this section.

Physical ergonomics concerns human anatomy, physiology, anthropometrics and biomechanics connected to the physical interactions the human has with other humans, systems, tools or products [5].

2.1.1 Physical loading

The primary structures in the body which together are able to resist different types of physical loading when the body is conducting work are mainly the skeleton, muscles and joints [6]. If the loading is more than the body can handle different types of injuries and overloading can occur. The physical loading can be divided into three factors consisting of posture, force and time that altogether affect the loading of the human body [6].

The body posture is connected to how the body is positioned while conducting the work and how it affects the body’s internal loading. The posture can be more or less controlled by the worker in how the worker chooses to position his/her body

while conducting the work or forced into a position due to outside factors that the worker can not affect (like for example available space for the worker) [6]. Space is one factor that can have an influence over the body posture of the worker, other ones are to have sufficient vision while conducting the work task, the stress level of the worker with high work pace or high mental loading, or due to protective clothing interfering and making it harder to conduct the work task [6]. Normally the farther away from the neutral position of an extremity (for example an arm reached out farthest from the body) the less optimal it is for external forces to be added to the extremity [6]. Force is the factor connected to external loading, like lifting, pushing or pulling a weight [6]. The time factor is connected to how often, how long and how frequently the body must endure physical loading [6]. According to Berlin and Adams [6] the most common part to focus on when assessing the time factor is how repetitive the work task is and thus how long time the recovery for the body is.

It is not one factor alone that makes the physical ergonomics a risk for the worker in the situation, thus a combination is critical for the evaluation [6]. The interaction between the three factors (posture, force and time) creates a total risk of the physical loading in the situation evaluated, seen to the probability and severity of the situation.

2.1.2 Cube model

The cube model takes the interaction of posture, force and time into consideration while evaluating how harmful different situations could be for the physical ergonomics [7]. The model was developed to classify and analyze work done with the use of hand tools [7]. In other cases, it can be used as a guiding reference but should be complemented with other methods in some cases.

The Cube model takes the three factors into consideration and provides the loading components with a severity level between one to three (where one is the lowest and three the highest) [6]. The factors are multiplied to gain the total risk factor that spans between 1 and 27. The Cube is divided into three zones; green, yellow and red, depending on the total risk number [6]. The green zone is the acceptable zone (risk number <6), the red zone is the non-acceptable zone (risk number >9) and the yellow zone needs to be investigated closer (risk number 6-9) [7]. Berlin and Adams [6] have made an illustration adapted from the original Cube model for hand tools made by Sperling et. al [7], see Figure 2.1.

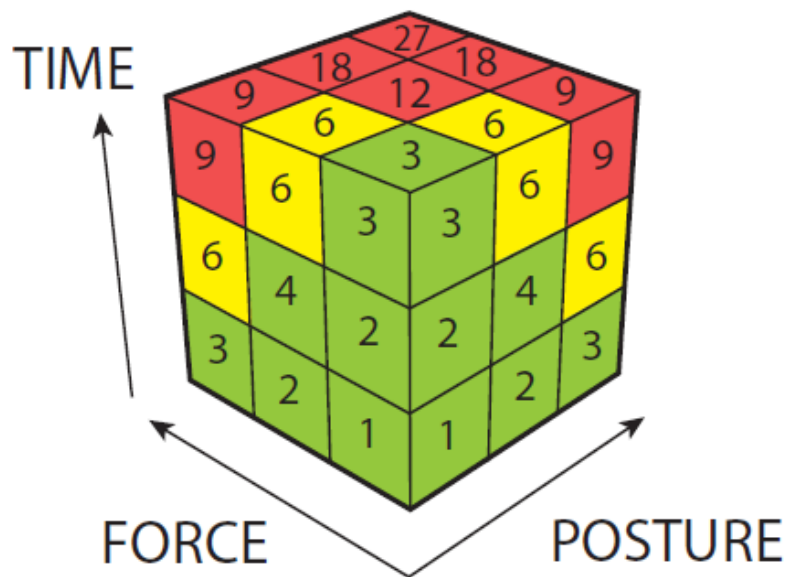


Figure 2.1: The cube model presents total risk for physical loading of three aspects. From [6]. CC-BY 4.0.

2.1.3 The Swedish Work Environment Authority models

The Swedish Work Environment Authority's (SWEA) provision 2012:2 [8] is made to facilitate better workplace and work task design to prevent musculoskeletal disorders. The models from the provision used for this study are presented below.

2.1.3.1 Model for assessing work posture

The model for assessing work postures while standing is divided into different areas of the body concerning the neck, back, shoulder/arm and legs [8]. Different situations and how often they occur are divided into three different severity levels, red (unsuitable), yellow (evaluate more closely) and green (acceptable). Table 2.1 presents a table adapted from the SWEA provision regarding work posture for standing positions.

Table 2.1: Model for assessing work posture. Adapted from [8].

	Unsuitable	Evaluate closer	Acceptable
	One of the following occurs during a significant part of the shift	One of the following occurs periodically during the shift	The following applies to a significant part of the shift
Neck	<ul style="list-style-type: none"> - flexed - twisted - simultaneously flexed and twisted - heavily restricted freedom of movement 	<ul style="list-style-type: none"> - flexed - twisted - simultaneously flexed and twisted - heavily restricted freedom of movement 	<ul style="list-style-type: none"> - upright posture - opportunity for free movements
Back	<ul style="list-style-type: none"> - flexed - twisted - simultaneously flexed and twisted - heavily restricted freedom of movement - unstable or inclined surface 	<ul style="list-style-type: none"> - flexed - twisted - simultaneously flexed and twisted - heavily restricted freedom of movement - unstable or inclined surface 	<ul style="list-style-type: none"> - upright posture - opportunity for free movements - opportunity to change to sitting-position
Shoulder/ Arm	<ul style="list-style-type: none"> - hand at or above shoulder height - hand at or below knee level - hand beyond 3/4 arm's length from the body 	<ul style="list-style-type: none"> - hand at or above shoulder height - hand at or below knee level - hand beyond 3/4 arm's length from the body 	<ul style="list-style-type: none"> - working height and reach adapted to task and individual
Legs	<ul style="list-style-type: none"> - inadequate room for legs and feet - unstable surface - inclined surface - leg- or foot-operated pedal work 	<ul style="list-style-type: none"> - inadequate room for legs and feet - unstable surface - inclined surface - leg- or foot-operated pedal work 	<ul style="list-style-type: none"> - freedom of movement on stable, non-slip even and level surface - no leg-operated and seldom foot-operated pedal work

2.1.3.2 Model for the assessment of lifting

The model for evaluation of lifting considers standing symmetrical lifting of burdens during ideal conditions and takes the distance the weight is from the lumbar spine and the weight of the burden into consideration [8]. The model is presented in Figure 2.2 and takes two situations into consideration, the first is when the object is within underarm distance from the body and the next is when the object is 3/4 arm's length away from the body.

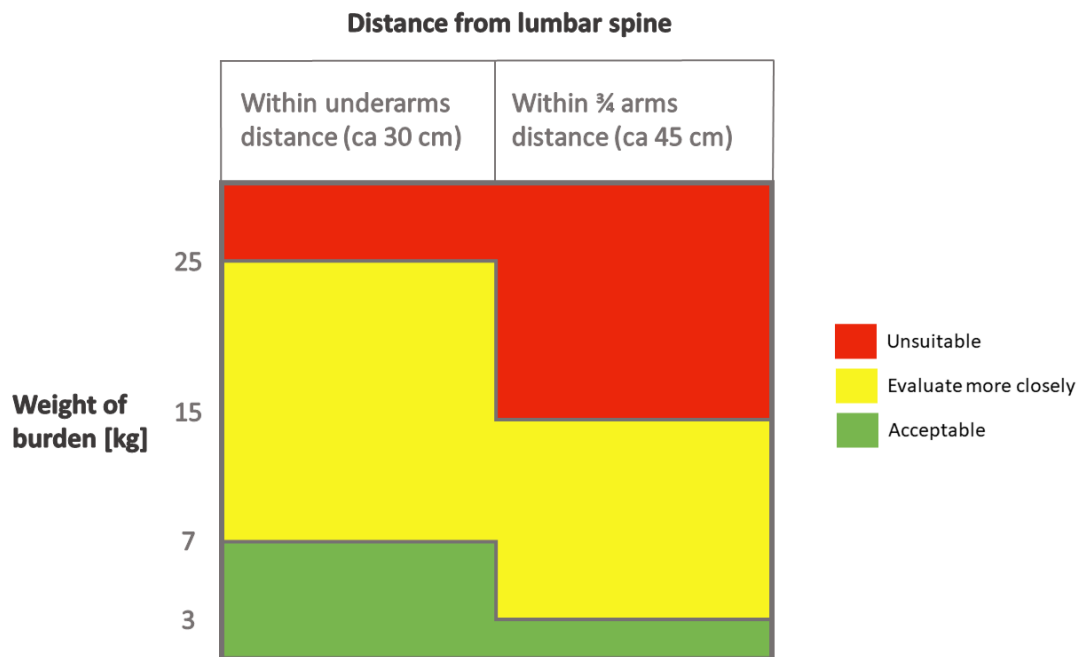


Figure 2.2: Figure illustrates a model for lifting conditions of burdens. Adapted from [8].

2.1.3.3 Model for identifying and assessing repetitive work

The model for identifying and assessing repetitive work from the SWEA takes four aspects into consideration: work cycle, work postures and working movements, job decision latitude and work content/training/competence requirements [8]. Table 2.2 presents the model where the red, yellow and green areas are the same as for the model of assessing work posture (unsuitable, evaluate more closely and acceptable). For assessing the repetitive work the most important factor is the work cycle, that is how long time it is between the same task being performed over again and how often this occurs during the work time (counted to normally be 7-8 hours per day) [8]. Assessment of work postures is also relevant in the repetitive work assessment. The job decision latitude limitations of the work can be if the worker cannot affect the work pace at a conveyor belt for example and the stress that might occur due to long queues of products or parts needing to be produced is another factor affecting the repetitive work [8]. The work content is controlled by the work tasks and how different the tasks are from one another, how much the worker can use their skills and knowledge to do the work. How much learning and constant training needed for doing the work task is included in this factor as well.

Table 2.2: Model for assessing repetitive work. Adapted from [8].

	Unsuitable	Evaluate closer	Acceptable
Work cycle	The work cycle is repeated several times a minute for at least half the shift.	The work cycle is repeated several times a minute for at least one hour of the shift or many times an hour for at least half the shift.	The work cycle is repeated a few times every hour
Work postures and working movements	Constrained or uncomfortable work postures and working movements.	Limited opportunities to change work postures and working movements.	Well-designed workplace. Good opportunities to vary work postures and working movements.
Job decision latitude	The work is completely controlled by other things or persons.	The work is partly controlled by other things or persons. Limited opportunities to influence how the task is performed.	Good opportunities to adapt the work to one's own ability. Influence over planning and arrangement of the work.
Work content Training/ Competence requirements	The employee performs an isolated task in a production process. Short training.	The employee performs several tasks in a production process. Job rotation can occur. Training for several areas.	The employee participates in several tasks or in the entire production process, including planning and control. Continuous competence development.

2.1.4 Anthropometry

Anthropometry is a part of the physical ergonomics that regards the human body's measurements [9]. It can be used when designing workplaces to find a solution that would fit most of the population by taking the body measures of different people into consideration [6]. People are different both on the inside and outside and therefore it is important to have an inclusive design for workplaces for a range of different people with different prerequisites.

One of the commonly accepted rules and design principles to adapt when taking different people into consideration is to rule out the extremes on both sides using the measures for 5th percentile women and 95th percentile men [6]. An example is that the shortest 5 percentile of the women and the tallest 5 percentile of the men are not taken into consideration when regarding the height of a person.

In theory, the anthropometric measures are supposed to cover 90 % of the work-

ers but since the different heights and lengths of extremities of a person are very individual some people are not in the upper 95th percentile in all of the relevant measures if more than one measure is taken into consideration [6]. This means that a bit less than 90 % might be taken into account if the principle of ruling out the extremes is adapted. If the design principle works for the specific case investigated needs to be evaluated from case to case [6].

The anthropometric measures used in this study are collected by Hanson et al. [9] and are meant to be a resource for product and production developers among others. In Table 2.3 a compilation of the relevant measures used in the study is presented. The measures regard the stature height, tibial length (knee level) and shoulder height for 5th percentile women, 95th percentile men and 50th percentile men and women.

Table 2.3: Stature height, Shoulder height and Tibial length for 5th percentile of women, 50th percentile of women and men and 95h percentile of men. Data from [9].

Percentile	Stature height [mm]	Shoulder height [mm]	Tibial height [mm]
<i>5th percentile W</i>	1562	1255	364
<i>50th percentile M/W</i>	1733	1407	429
<i>95th percentile M</i>	1907	1562	508

2.2 Tracking systems

Different technologies used in tracking systems exist on the market today. In this section, a summary is presented of some of the most commonly used technologies.

The possibility to track and trace products throughout their process is used in many different business areas to provide a better knowledge of where the products are located for the company or customer and to achieve higher productivity in the process. The track-and-trace system (further called tracking system) is divided into two parts, tracking and tracing. According to Shamsuzzoha et al. [10] the difference between tracking and tracing is that tracking is the ability to see the current location of the product. Traceability on the other hand is defined as the ability to go backward in the chain and trace the history when the product has gone through different steps in the process [10]. It becomes more and more important to be able to track and trace products through its entire process [10].

Different positioning systems can be divided into either outdoor or indoor positioning systems [11]. Some of the most common logistic tracking technologies are described further below.

2.2.1 Outdoor positioning technologies

The outdoor positioning technology is commonly used for outbound logistic systems between different companies since it is an easy way of knowing where the products are located without implementing a massive system for all companies [11]. Two of the most used outdoor positioning technologies are GPS (Global Positioning System) and GSM (Global Systems for Mobile Communications).

2.2.1.1 GPS tracking

GPS tracking enables real-time tracking of products and works well outdoors [11]. GPS is a satellite-based system that can make it difficult to be used indoors since the positioning of a product can be restricted due to external factors like the walls of the building and metallic objects [11]. The GPS system can have an accuracy of 10-100 m depending on the equipment and devices [10].

2.2.1.2 GSM

Another outdoor positioning technology is the GSM used in mobile communication technology [11]. The system is globally accepted and the device uses a cellular network searching actively for cells around itself and connect to the closest ones to define where the device is located [12]. The GSM method will be used until 3G and 4G mobile tracking becomes more comprehensive [11].

2.2.2 Indoor positioning technologies

The indoor positioning systems are often used in so-called indirect distribution, meaning internally at a company before it is sent away to the end location [11]. The most common indoor positioning systems are barcodes and RFID systems. To be able to use barcodes or RFID technology readers installed in the logistic path are a must [13]. Barcodes and RFID systems are so-called event-monitored systems since they use predefined fixing points where the barcodes or RFID tags are registered [13]. Because of this, there is no way of knowing what happens in between the fixed positions in the process.

2.2.2.1 Barcode - 1D and 2D

Barcodes are commonly used to identify products [14]. 1D barcodes have limited possibility of storing data and are made up of vertical lines and spaces [14]. Because of this, the 2D barcode (QR-code) was developed enabling more data to be stored in a data matrix consisting of filled in or empty squares [14]. The usage of barcodes

is relatively simple, with a minimum of a smartphone camera and an internet connection [11].

2.2.2.2 RFID

The RFID (Radio Frequency Identification) technology, is a wireless and automatic identification (auto-ID) technology enabling the system to gather data information without any physical connection or direct interference and without the help of humans [15]. According to Tajima, [15] a basic form of an RFID system consists of two parts, a tag and a reader. The tag consists of an antenna enabling information to be transmitted through radio waves to the reader and a microchip that stores the information enabling the product to be identified [15]. When the information is received by the reader through radio signals from the tag it sends it further to a computer database storing the information and enabling it to be used for different purposes and decisions (manual or automated) [16]. The RFID reader can quickly gather information through communication with a large number of tags [16].

3

Method

The project was conducted at Schenker AB's head office in Gothenburg with terminal visits made at two terminals, one large-sized (Gothenburg) and one medium-sized (Växjö). This section will describe the methods used in the project and the project's process. A triangulation of methods including literature studies, quantitative studies and qualitative studies was used in this project to get a more comprehensive understanding of the project and its specific parts.

3.1 The project's process

The study consists of three different areas: the current solution, the new solutions and the comparison between the new solutions and the current state. The procedure of the project is divided into four tasks with three of them being divided into two tracks. Figure 3.1 presents the procedure and areas of the project.

The Covid-19 situation affected mostly the data gathering of the project. Due to the situation, the data gathering could only be conducted at two terminals. After the first terminal visits, the possibility to go back to the terminal to do further investigations was not possible due to new restrictions concerning the entire community, of which Schenker of course set the same restrictions for their workers. The evaluation of the new solutions, regarding the new cage size and the new tracking system, were made at a theoretical level, since the possibility to exam the new solutions in the production was limited due to the new restrictions among other factors. The choice of methods used in the project was not greatly affected by the Covid-19 situation. Some smaller changes were made e.g. an interview was conducted online rather than in real life.

3.2 Defining and analyzing current solution

The purpose of defining and analyzing the current solution was to map the current parcel-cage process and to gain an understanding of how the current solution works and the possible problems with it. The methods used in this process and the steps taken are described further in this section.

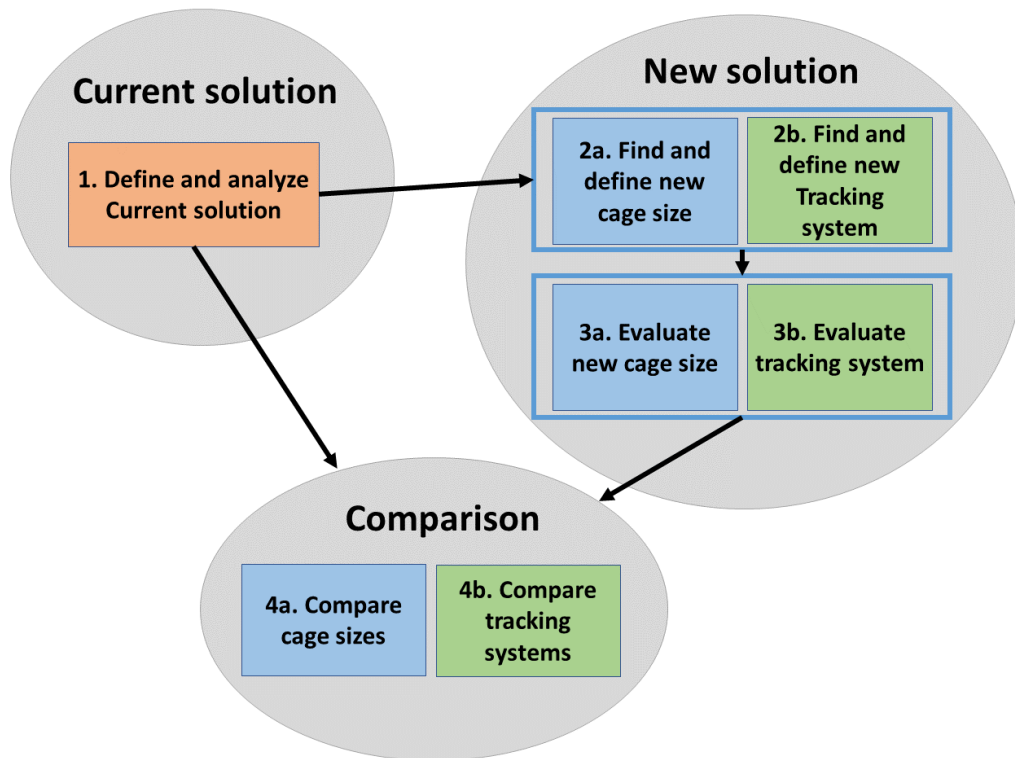


Figure 3.1: Illustration of the project's process.

3.2.1 Literature study

A literature study aims to search for information in published data systematically and can be helpful when choosing relevant methodology to use in the study or when more information is needed in a specific area of interest [17]. The study explores what has already been written within the field [17].

The literature study conducted in this master's thesis was an iterative process and consisted partly of finding and evaluating different methods used in the project and partly by getting a deeper understanding and knowledge of primarily the logistics area, transport efficiency, ergonomics and tracking systems.

The articles were chosen based on how well their content was consistent with the aim of the literature study. Aids like Chalmers University of Technology online database collection and Google were used when searching for relevant information. Databases used were *Science Direct*, *Research Gate* and *Emerald* among others.

3.2.2 Quantitative study

Quantitative studies are conducted by collecting, analyzing and explain numerical data to understand how the studied subject functions [18]. Large numbers of samples are needed to make an accurate and reliable analysis. Quantitative studies are

normally not conducted in a natural setting and it does not let participants explain the reason to why they did as they did [18]. On the other hand the method provides objectivity to the study and takes relatively little time thanks to for example reliable software systems enabling even large data sets to be analyzed within a reasonable time [18].

The quantitative study in this project concerned data gathering from a statistical tool (Qlikview application) and analysis of the data. Datasets of different sizes were gathered and analyzed to see patterns and trends to determine if the data was reliable and relevant. The data gathered and used in the analysis were over an entire year.

3.2.3 Qualitative study

Qualitative studies aim to collect, analyze and explain non-numerical data in a natural setting, such as what is happening, the reasons behind it and people's motivations [18]. Commonly used qualitative methods are interviews and observations. An advantage with the qualitative method is the meaningful and insider insight the method can bring to the study since it is conducted "in the field" in the natural settings [18]. At the same time qualitative studies are time consuming and subjective to the person conducting them [18].

It is important to be able to identify and understand the difference between how things are planned to occur and how things occur, especially when dealing with human workers [6]. In a complex situation it could help to break the job down into smaller parts to help see the difference between what the meaning behind a job is and what is happening [6].

The qualitative study was performed at two different terminals in Sweden and four different shifts: two departing and two arriving shifts. The parcel-cage process and other information can differ between different-sized terminals, local routines and depending on worker at each terminal. It was therefore crucial to gain knowledge of how the process is conducted at different terminals. It was also important to gain knowledge from the workers at the head office since they generally has a broad knowledge within the area.

3.2.3.1 Data gathering

The qualitative study consisted of two different parts, observations and interviews. Observations should be conducted when the researcher wants to understand what workers are doing and how the interaction between humans works [19]. The study began with informal observations to understand what work tasks were conducted and the interaction of terminal workers and truck drivers in the process. Informal observations are conducted by observing what is happening in the environment to gain initial insights into the observed situation or workers [19]. The same procedure

was adapted to the different shifts and terminals.

To make more sense of the observations done interviews are typically conducted [19]. This allows the information from the observations to connect to different interactions and behaviours of the workers [19]. Semi-structured interviews were used in this project to understand and gather information regarding why the workers perform the tasks the way they do and how they are thinking about different things. Semi-structured interviews normally uses a mix between open- and closed-ended questions with follow-up questions like *how* or *why* [20]. Advantages are that the questions asked are relevant to the topic and comprehensive since they are well prepared before the interview starts [20]. The data gathered in the interviews are also easier to compare between each other and find patterns [20]. Disadvantages with the interview form are the amount of work and time needed to conduct them, compared to other types of interviews [20]. 12 semi-structured interviews were conducted with terminal workers, team leaders and terminal managers. The base questions asked in the interviews can be found in Appendix A. The interviews generally concern the same areas of questions, however, they depend on who the interviewee is. The questions asked to the terminal workers were more operative while the questions for the terminal managers were more on a strategic and general level. The questions concerned the areas: work tasks regarding parcel handling and parcel-cages, ergonomics, handling of cages and current tracking system. The questions differed a bit between the departing and arriving terminal since the work tasks differ. In some cases, a more adapted "on-the-go" version of the semi-structured interviews was needed with truck drivers and additional terminal workers due to time limitations and their work situation. The majority of the interviews were able to be conducted at the terminals but due to Covid-19 one of the interviews was done digitally.

3.2.3.2 Data analysis

The data gathered from the observations and interviews were summarized in text and further analyzed with the K-J method to find patterns and important information. The K-J method (also known as affinity diagram) is used to reduce a large amount of data to a few key ideas [21]. The method categorizes the data gathered in previous steps into groups making it easier to see patterns and to analyze the data further [21]. Further analysis of the data was made with lists and visualizations to deepen the knowledge of how the data is connected.

3.2.4 Calculating transport efficiency

A first step for calculating the transport efficiency was to understand the data gathered in the Qlikview application and determine if the data was reliable and could be used for a specific purpose. Different time spans were investigated to see trends in the data and compare it to the information received in the qualitative study at the terminals. It was important to find correct data so that the parcel-cages were only counted one time per sending, that empty cages transported between terminals

were not counted and that the written number of cages sent was relevant and reliable. Once again information from the qualitative study was used to see if what the workers put into the system could be accurate for what was actually transported. The larger transportation flows were investigated more closely since they are a larger part of the data and it is important that it is correct. The transport efficiency was calculated as an average number of parcels per pallet place over a year counting the parcels and parcel-cages sent from most of the terminals, with the exception of two terminals that had written the number of parcel-cages sent to other terminals in an incorrect way. The calculation made to get the current transport efficiency is seen in Equation 3.1.

$$\text{Current transport efficiency [psc]} = \frac{\text{Parcels transported}}{\text{Cages transported}} \quad (3.1)$$

Another way of measuring the transport efficiency of a carriage is through the performance measure called "Load factor". The load factor is a way of measuring how much of the truck is utilized when transporting goods in a vehicle, described as the ratio between the actual used capacity and the maximum capacity available measured in percentage [22]. Some common effects of more efficient transport of goods in vehicles are reduced costs and reduced transport emissions [23]. The load factor is in this project calculated as the total volume of the parcel-cage divided by the total available volume for a pallet place in the carriage, see Equation 3.2.

$$\text{Current load factor [\%]} = 100 * \frac{\text{Total volume of parcel-cage}}{\text{Available volume in carriage}} \quad (3.2)$$

3.2.5 Evaluating handling of cages

To understand how the handling of the cages is done for the current parcel-cage process the two terminals' actual processes were studied and mapped with a flow chart process map. This was done with observations and interviews to understand the relevant work tasks, their interrelations and the human interactions in the process.

3.2.5.1 Process mapping

Process mapping is conducted to thoroughly understand a process and visualize inputs, actions and outputs of the process in a graphical step-by-step map [24]. A well-developed process map can help in decision making since it can identify strengths and weaknesses in the current situation of the process [24]. The process map can include not only the input, actions and output of the process but also interactions with human workers. Process mapping can be very helpful in improvement work and it can be a tool to understand where waste occurs in the process to eliminate or reduce it [24].

However, some processes are not optimal for the use of process mapping, e.g. if the process is intangible and abstract [24]. The process map is often used to find the

root cause of a problem, but if the focus is wrong with the process mapping the real problem might be outside the scope [24]. Another very important factor is to identify the actual process, not the intended one. If the intended process is mapped the real problems will be harder (or impossible) to find [24]. The steps to conduct a process map are described below [24].

1. Select the process and reason behind
2. Identify scope of the process
3. Plan and schedule resources
4. Select mapping technique
5. Conduct interviews
6. Describe the actual process
7. Analyze, evaluate and Sign-off

A process flowchart is one of the typical process maps that show points of decisions and the sequence of activities [24]. It can be expanded to deal with the work tasks and roles of the workers as well as to gain a broader understanding of the process. To understand the parcel-cage process a general process map consisting of sub-goals for both of the terminals was compiled.

3.2.5.2 HTA - Hierarchical task analysis

One way of breaking down a job or process into smaller tasks is with the HTA methodology (Hierarchical task analysis) [25]. The method consists of different layers of tasks in a hierarchical structure with the goal of the job as the highest point followed by tasks, sub-tasks and the very lowest and most simple operations in the bottom [6]. Stanton [25] distinguishes between different hierarchical goals where the highest goal for the system is called super-ordinate goal (further called system goal) and the goals needed to be accomplished for the system goal to be achieved, the subordinate goals (further called sub-goals) [25]. Figure 3.2 presents an illustration of the HTA hierarchical terminology and structure adapted from Berlin and Adams [6]. The terminology and structure from HTA is used in this master's thesis to show the connection between system goal, sub-goals and work tasks easily and understandably.

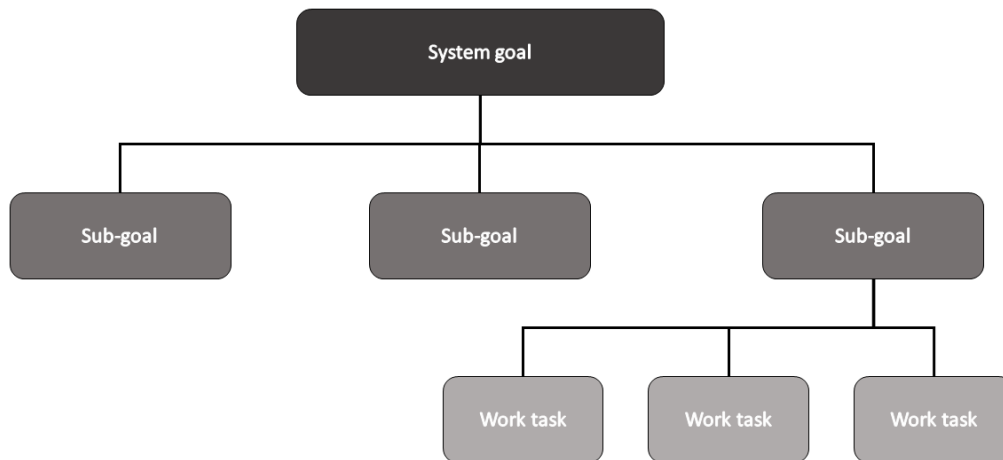


Figure 3.2: HTA hierarchical terminology and structure. Adapted from [6]. CC-BY 4.0.

3.2.6 Defining and evaluating physical ergonomics

The interviews and observations made for the current solution collected data of how the terminal workers pack their cages, both their packing strategies and their potentially harmful behaviours.

The model used as an inspiration and guiding tool to do an evaluation of the physical ergonomics risks in packing parcels in the cage is the Cube model developed by Sperling et. al [7]. The Cube model was originally developed to evaluate work done with hand tools to understand if the work situation was acceptable or non-acceptable [7]. Many different situations can occur while packing parcels into the cage. This project regards the three aspects evaluated in the Cube model: the posture of the worker, force (weight of parcel) and time conducting the work. The interaction between the aspects is what creates risky situations or not [7]. The different situations identified received a severity level based on evaluation of the aspects from several of the SWEA models in their provision regarding the prevention of Musculoskeletal disorders from 2012 [8]. Based on this an evaluation of different situations was done to understand which situations were potentially harmful. Other methods for evaluating physical ergonomics exist as well. However, for this purpose, they were very detailed and depended on specific situations, while this project regards a more general evaluation of the current parcel-cage's packing situation.

3.2.7 Evaluating tracking system

The qualitative study gathered and analyzed data regarding the currently used tracking systems using interviews, observations and K-J analysis. Problems with tracking today and reasons behind why cage shortage occur were identified.

3.3 Defining and evaluating the new solution

The two tracks of the new solution are defined and evaluated separately.

3.3.1 Defined optimal cage size

The first step in finding the optimal cage size was to conduct a quantitative study collecting data on the inside heights of the carriage and the bar height. This was done with help of the five largest haulage companies in the linehaul transportation distances. The maximal inside height of the cage was calculated with half of the free height of the inside (inside height of the carriage minus the bar height) minus the EUR pallet height measured in millimeters, see Equation 3.3.

$$\text{Cage maximal inside height [mm]} = \frac{\text{Carriage inside height} - \text{Bar height}}{2} - \text{EUR pallet height} \quad (3.3)$$

The margin between the cage's top and the inside roof or the bar was calculated according to Equation 3.4 and measured in millimeters. It can be calculated by subtracting the outside height of the parcel-cage (inside height + EUR-pallet height) with half of the free inside space (consisting of the inside height of the carriage minus bar height) since it should be two cages on one pallet place.

$$\text{Margin [mm]} = \frac{\text{Carriage inside height} - \text{Bar height}}{2} - (\text{Cage inside height} + \text{EUR pallet height}) \quad (3.4)$$

3.3.1.1 Evaluation of optimal size

After the optimal size was calculated a consequence analysis regarding how the new cage would affect the current parcel-cage process was performed on a work-task level. This consequence analysis was inspired by FMEA (Failure Mode and Effect Analysis) methodology to gain broad knowledge regarding what risks each of the work tasks could provide for the entire process, both positively and negatively. The factors evaluated were time, physical ergonomics, transportation efficiency and environmental impact.

FMEA - Failure Mode and Effect Analysis The FMEA (Failure Mode and Effect Analysis) method has the purpose of analyzing new or already existing processes or products to identify and prevent possible problems/failures with the end product or process. Possible defects or safety failures could be detected and avoided with design changes in early stages [26]. An FMEA consists of an identification part of different failures that could occur, an evaluation for the risk of failure and an assessment prioritizing the highest risk priority number. The evaluation for the risk of failure is done by multiplying the three factors with each other to gain an overall assessment of relative risks [26]. The factors are the severity of the failure if it would occur, the probability for the failure to occur and the possibility to detect the problem before it occurs [26]. The highest risk priority numbers after the evaluation should be addressed first.

Transport efficiency The transport efficiency for the new parcel-cage was calculated by using the volume difference between the current and new parcel-cage and the average number of parcels sent in a pallet place for the current cage, as calculated previously. Equation 3.5 shows the calculations done. The new solution can fit two parcel-cages in one pallet place, thus the inside volume of the new cage is multiplied by two. The load factor was also calculated for the new parcel-cage.

$$\text{New transport efficiency [psc]} = \frac{\text{Inside volume alt. cage} * 2}{\text{Inside volume current cage}} * \text{Current transport efficiency} \quad (3.5)$$

The change in transport efficiency is calculated as the quotient between the new and current transport efficiency measured in percentage, see Equation 3.6.

$$\text{Transport efficiency change for new cage [\%]} = 100 * \frac{\text{New transport efficiency}}{\text{Current transport efficiency}} \quad (3.6)$$

Time factor In the time factor, the change in time is based on how many more parcel-cages are needed for the same number of parcels to be transported. The change in the number of cages is the proportion between how many cages will be needed for the new cage and how many cages are needed for the current cage for a fixed number of parcels. The calculation is based on the average number of parcels being able to be transported for the current and the new cage measured in percentage, see Equation 3.7. The new transport efficiency is calculated for two cages (a pallet place), thus division by two is needed to get the accurate number for one cage.

$$\text{Proportion more cages needed [\%]} = 100 * \frac{\text{Current transport efficiency}}{\text{New transport efficiency}/2} \quad (3.7)$$

Physical ergonomics Regarding ergonomics, the work tasks relevant for a change were evaluated based on the change in working height. The physical ergonomics for the new parcel-cage size is measured by calculating the acceptable and unsuitable lifting heights in the cage, described as a percentage of how often the lifts end up in either of the lifting zones.

3.3.2 Tracking system

A literature study was carried out to find what types of tracking technology existed on the market today, how they could be used in the future and what technology is commonly used within the specific area investigated. The study was analyzed and possibilities for the technology for the tracking system were evaluated, as well as how it could be implemented and used in the future.

3.3.3 Comparing the current and new solution

The comparison between the current and new solutions was made to gain a better overview of how the change could affect different factors which in turn affect the parcel-cage process. The factors evaluated in the comparison are time, transport efficiency, physical ergonomics and the tracking system.

4

Results

4.1 Current Solution

This section is divided into transport efficiency, process mapping, physical ergonomic evaluation and the tracking system. The section presents the current solution in connection to transportation, handling and tracking of the current cages.

4.1.1 Mapping of current parcel-cage process

To understand the current handling of the cages it is first important to map the current parcel-cage process to understand which work tasks which are connected to the cages, how they are connected with each other and the human interactions in the process.

The qualitative study at the large-sized and medium-sized terminals resulted in two different process flowcharts (see Appendix C) where different work tasks in the parcel-cage process were mapped. One or more work tasks lay the foundation for a sub-goal to be achieved. The terminals have the same sub-goals but perform the work tasks a bit differently regarding how and when they are done. A simplified and general process flowchart, taking both the large-sized and medium-sized terminals into consideration, is presented in Figure 4.1. The flowchart focuses on the sub-goals in the process, how they are connected with one another, in what order they are performed and who is responsible for performing the sub-goal. The start point of the parcel-cage process is a need to transport parcels from the departing terminal, T1, to the arriving terminal, T2. The endpoint is the successful transportation of parcels to the correct arriving terminal. The start and endpoints are connected to the system goal of the process, that is to safely transport parcels from one terminal to another. The sub-goals are goals that need to be fulfilled in order for the system goal to be achieved. The sub-goals conducted at the departing terminal, T1, are presented on the left-hand side of the figure and the sub-goals conducted at the arriving terminal, T2, are presented on the right-hand side of the figure. Six different major fields were identified within the process, three of them being at the departing terminal (Preparation for production, During Production and After production), one is in between the terminals (Transportation) and two of them at the arriving terminal (Preparation for production and During production), here represented with large fields in different colors. The small rectangles are sub-goals needed to be accomplished for the process to be succeeded and finished. The colored dots inside the

squares shows who is responsible for each sub-goal to be done. Some sub-goals and work tasks can be conducted by more than one worker. The diamonds in the process map are when a decision needs to be made affecting the next step in the process.

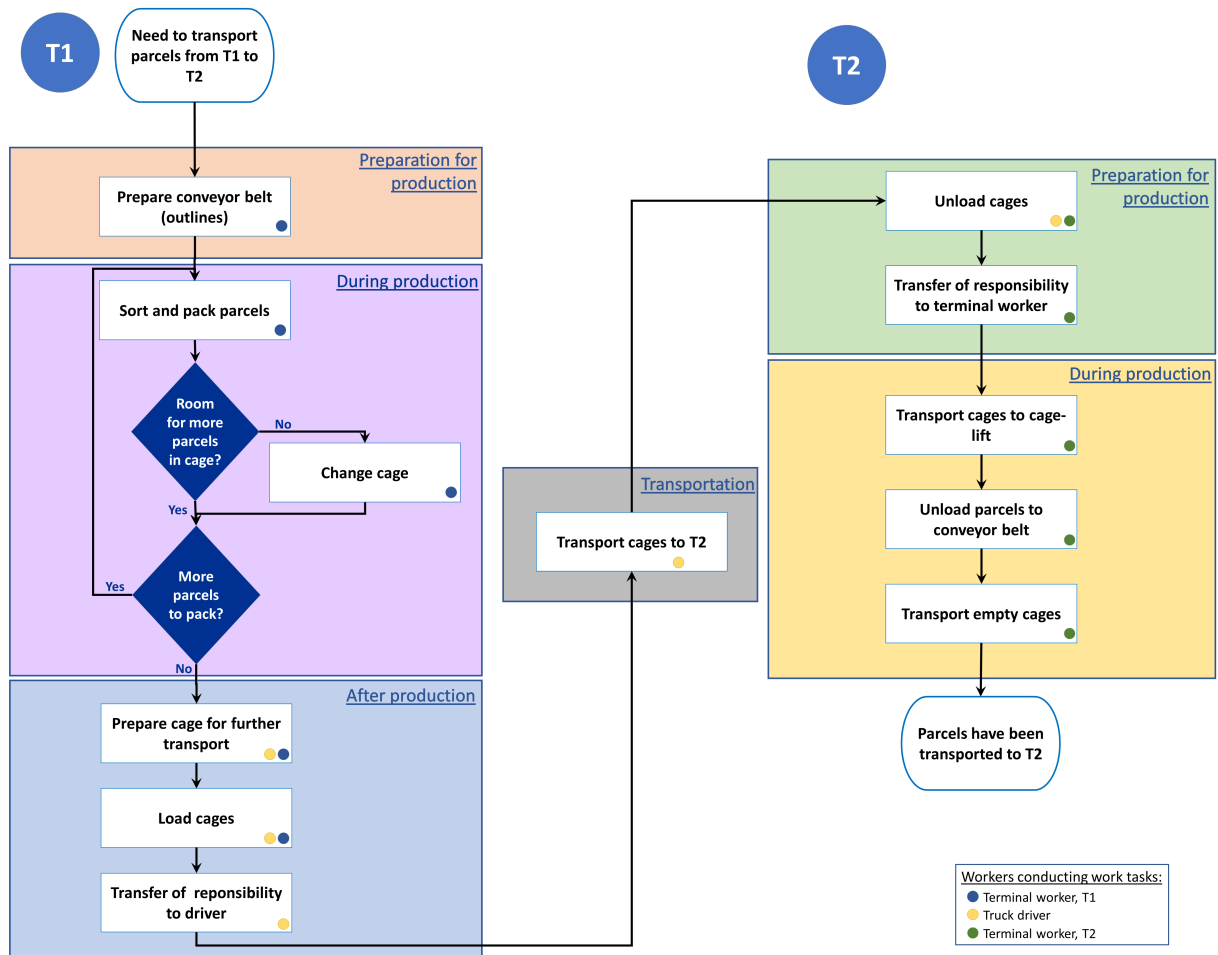


Figure 4.1: Simplified and general process map focusing on the sub-goals in the process.

As mentioned previously, all the sub-goals in Figure 4.1 are connected to different work tasks conducted by the terminal worker or truck driver. Table 4.1 and 4.2 presents a connection between the sub-goals and the work tasks and who is responsible for the work task. A work task can occur in several sub-goals at different times in the process. An example is the work task closing the cage by putting on a gate that occurs in the sub-goal when a parcel-cage is changed during production as well as when preparing the cage for further transportation after production.

Table 4.1: Sub-goals and work tasks occurring at the departing terminal, T1.

Sub-goal	Work tasks	Responsible worker
Prepare conveyor belt (outlines)	-Put empty parcel-cages at outlines -Put on Cage flag and scan it in the Cage app and fill in list over how many cages that are sent	
Sort and pack parcels	-Fetch parcel from conveyor outline -Pack parcels in the correct parcel-cage -Close parcel-cage with gate -Transport cage to buffer with ready cages	Terminal worker (T1)
Change cages	-Transport empty parcel-cage (from empty cage buffer) to outline -Put on Cage flag and scan it in Cage app and fill in list over how many cages that are sent -Close parcel-cage with gate	Terminal worker (T1) / Truck driver
Prepare cage for further transport	-Print out transportation document -Give transportation document to driver	Terminal worker (T1)
Load cages	-Scan transportation document -Alt. 1: Terminal worker load cage to agreed place -Alt. 2: Driver picks cage up at outline/buffer of ready cages	Truck driver Terminal worker (T1)
Transfer cage-responsibility to driver	-Driver takes over responsibility for cages	Truck driver

Table 4.2: Sub-goals and work tasks occurring in between terminals and at the arriving terminal, T2.

Sub-goal	Work task	Responsible worker
Transport cages to T2	-Driver transport cages with truck -Driver scan transportation document -Driver leaves transportation document to terminal worker	Truck driver
Unload cages	-Alt. 1: Driver unloads cages to agreed place -Alt. 2: Terminal worker unloads cages from agreed place to buffer	
Transfer cage-responsibility to terminal worker	-Terminal worker takes over responsibility for cages	
Transport cages to cage-lift	-Open cage: take away gate -Transport cage from buffer or carriage to cage-lift	Terminal worker (T2)
Unload parcels at conveyor belt	-Unload parcels from cage-lift to conveyor belt	
Transport empty cages	-Transport empty cage to empty cage buffer	

4.1.2 Transport efficiency

This section presents the result of the current transport efficiency calculations based on data from the Qlikview application. The load factor is calculated for the current parcel-cage.

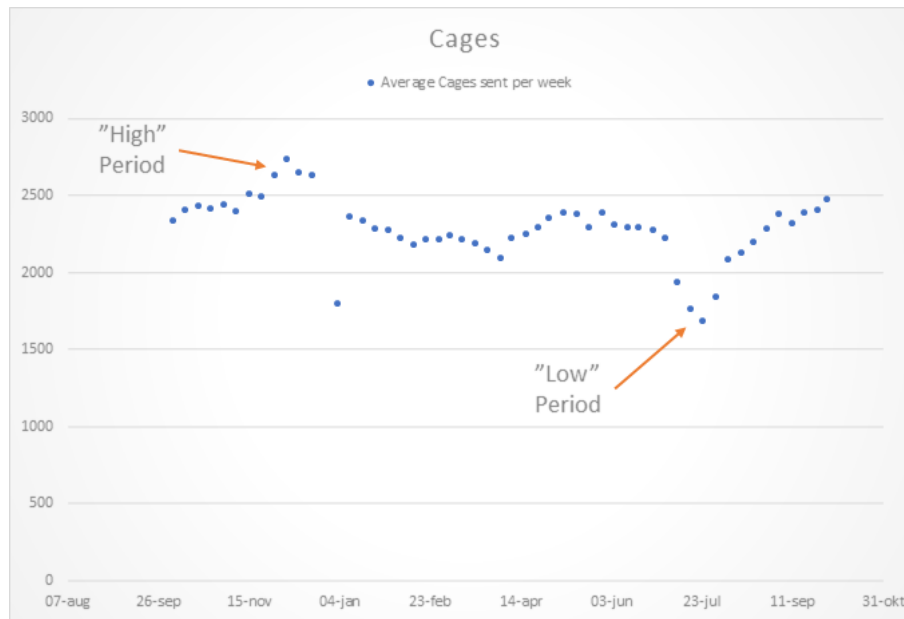
4.1.2.1 Reliable information

To understand whether the data in the Qlikview application is relevant and reliable to use in the transport efficiency calculations an analysis of the data was made. Information in the system was validated through comparison with information gathered in the qualitative study. In some areas, incomplete data made it impossible to draw reliable conclusion. The data chosen to not be regarded in the study for parcels and cages are presented in Appendix B.

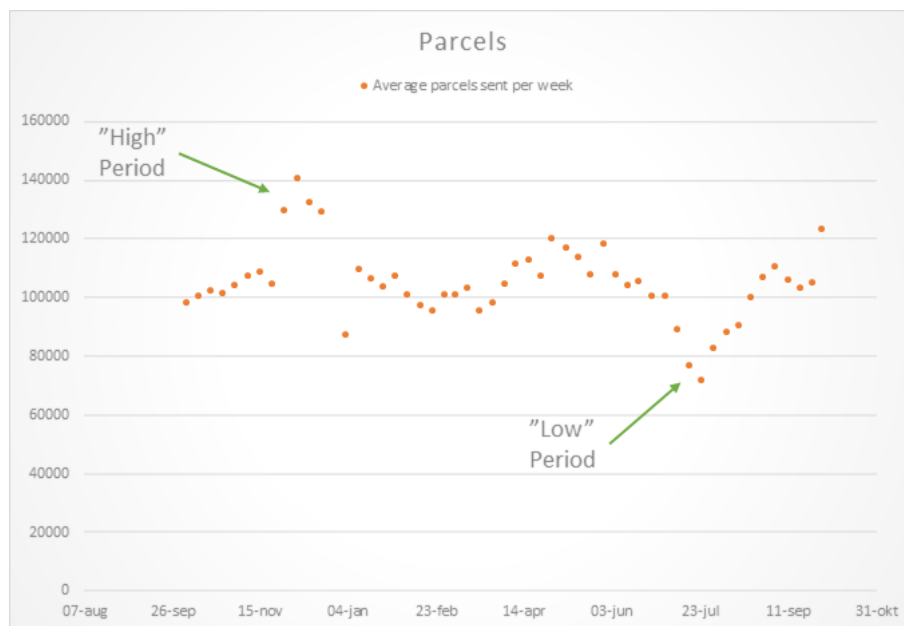
4.1.2.2 Patterns and trends in data

The analysis of the data collected in the quantitative study was compared to data gathered in the qualitative study. Data was analyzed over one year (October 2019

- September 2020) and shows three different trend periods, see Figure 4.2. The "High" period appears during November and December, affected by the large number of parcels sent during Black Friday and Christmas shopping. The "Low" period occurs in the summer months, mainly in July, when companies send fewer parcels and when the industrial vacation occurs. During the rest of the year, mostly spring and autumn, the parcel and cage numbers sent are fairly even, making these periods to the "Medium" period, which is in between the high and low periods in Figure 4.2.



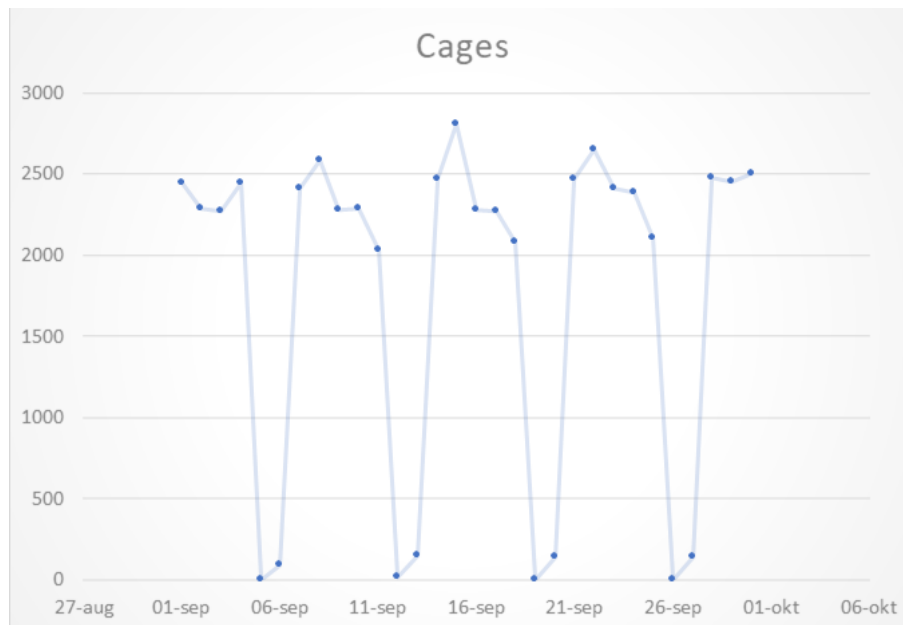
(a) Cages sent over a year.



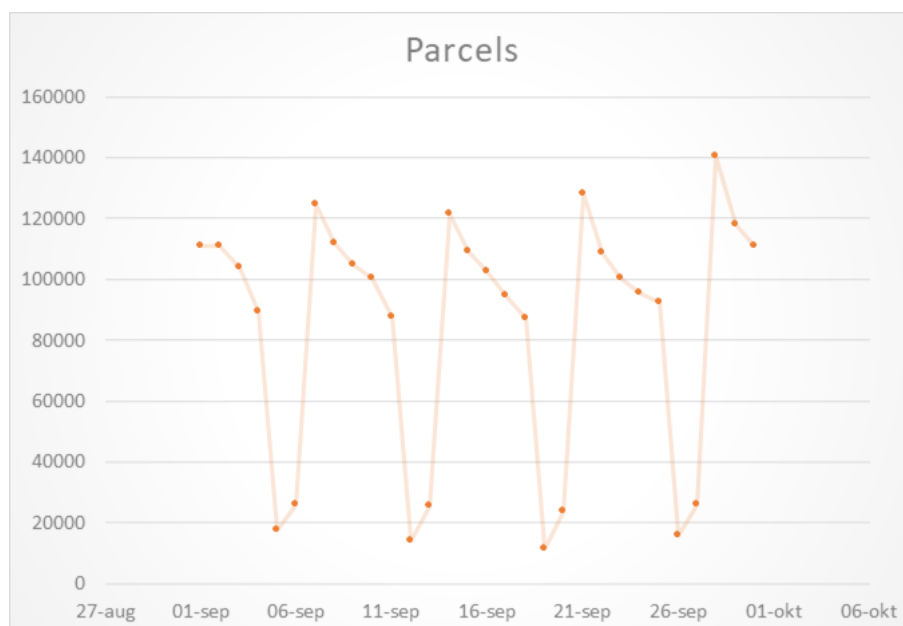
(b) Parcels sent over a year.

Figure 4.2: Number of cages and parcels sent in one year.

A period of one month (September 2020) gives a good overview of the parcel and cages sent each day for the relevant data, see Figure 4.3. Both figures indicate more parcels and cages being sent at the beginning of the week, just after the weekend, and decreasing towards the end of the work-week, just before the weekend. This pattern was also confirmed by interviews with the workers at the terminals. Since the departing shifts normally work Monday to Friday there are normally no parcels and cages being sent in between terminals on the weekends. During the weekend some parcels are registered as being sent since they for example are scanned at an authorized representative for further transportation the following weekday. Normally no parcel-cages are sent between terminals during the weekends, however, some cages are registered as sent due to for example how preparations are done at some terminals or because of a few relations sending some parcels during Sundays at some terminals.



(a) Cages sent in September.



(b) Parcels sent in September.

Figure 4.3: Number of cages and parcels sent in September.

4.1.2.3 Calculating the average number of parcels sent per cage

After analyzing the data provided in the Qlikview application the relevant data was used to calculate the average number of parcels sent in one parcel-cage. Table 4.3 presents an average number of parcels, cages, and parcels per cage sent over each month of the year. An average number for each of the interesting factors is summarized in the bottom of the table, resulting in an average of 49,6 parcels sent in each parcel cage. Naturally, it is not possible to transport parts of a parcel,

however, since the parcels vary in size the decimals will be counted for the result. Figure 4.4 presents the number of parcels sent per cage for each month over the year.

Table 4.3: Number of parcels, cages and average number of parcels per cage sent for each month.

Month	Parcels	Cages	Parcels/Cage
October 2019	2 495 136	42 743	58,4
November 2019	2 522 089	44 686	56,4
December 2019	2 598 798	45 341	57,3
January 2020	2 376 088	45 678	52,0
February 2020	2 123 181	46 144	46,0
March 2020	2 390 446	46 379	51,5
April 2020	2 420 272	48 160	50,3
May 2020	2 453 742	48 683	50,4
June 2020	2 363 881	48 933	48,3
July 2020	2 000 841	52 573	38,1
August 2020	2 223 388	52 889	42,0
September 2020	2 513 745	56 006	44,9
Mean value	2 373 467	48 185	49,6

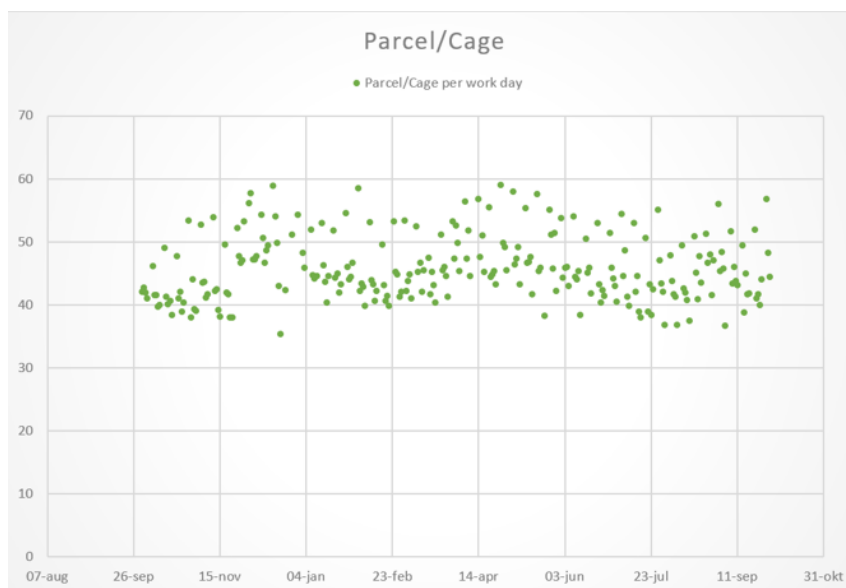


Figure 4.4: Average of parcels sent per cage over a year.

The current load factor for the cage in the carriage is calculated with the used volume for the cage and the available volume of one pallet place. The current load factor is 62,8 % and the result is presented in Table 4.4.

Table 4.4: Result of load factor calculations for the current cage.

	Current cage
Used volume per pallet place [m ³]	1,87
Available volume per pallet place [m ³]	2,98
Load factor (used volume/available volume) [%]	62,8

4.1.3 Physical ergonomics evaluation

In the current state analysis, the most vulnerable areas of the body where injuries or overloading may happen are identified as the back, shoulders, arms and head indicating the need for change to prevent harmful loading in these body parts. The United States Occupational Safety and Health Administration (OSHA) identifies in particular lifts ending over shoulder height to put stress on the upper back, arms and shoulders [27]. Also when lifting heavy loads (>15 kg when not able to hold the load close to the body) the lumbar spine (lower back) is especially exposed to injuries and overload [8].

The literature study combined with the current state analysis suggests two areas that have the worst physical ergonomic risk in the parcel-cage process. One of them is the sorting of parcels in the cages at the conveyor belt outlines. The other one is when parcels fall out from the cage harming workers and getting damaged when opening the gates or when emptying them to the conveyor belt.

How the workers pack the parcels into the cage has a large impact regarding both the physical ergonomics for the worker and the reasons why parcels fall out of the cages. Due to these findings in the current state analysis, the ergonomic evaluation will focus on the sorting of the parcels into the cages. When packing parcels into a cage the workers have different strategies of how they conduct the work task. The identified strategies are described in this section along with an analysis of potentially harmful situations occurring when packing parcels into the cage. Different situations that can occur while packing a cage (weight of parcels and where they are placed in the cage) are analyzed as well.

4.1.3.1 Strategies for packing parcels into a cage

An important part of the packing of parcels into the cage is to maximize the utilization of the cage. However, from the current state analysis, it is also very important how the cage is packed to prevent parcels from falling from the cage later in the process. During the interviews, important knowledge was shared from the workers about how they are thinking when packing the cage to optimize the utilization and minimize the possible risk of parcels falling. Through the worker's experience, useful

information and behaviour that should be promoted could be compiled into common strategies shared by the workers and specific strategies. Firstly, the worker's motivations for following their strategy are presented.

Reasons for packing strategies There are some different motivations for the workers to have a strategy when packing the parcel-cages. One motivation is to reduce the risk of parcels falling and hurting workers at the arriving terminal. Another one has to do with minimizing the overload and injury-risk of their bodies when packing the parcels. How well they are doing their job by optimizing the utilization of the cage and minimizing damage to parcels is another motivation.

Common strategies A common idea for the workers is to first gain knowledge of the weight of the parcel from either looking at it and/or lifting it, since for example some parcels can be very heavy but with a rather small volume. To be able to create a stable bottom the heavy parcels should be put in the bottom of the cage. Softer and/or light-weighted parcels should go on top in the cage to avoid damage risk. Another general idea from the workers is to try to place the parcels with as little space in between them as possible and fitting them into the free space implementing the "Tetris way" to optimize the utilization of the cage.

"Stable walls" A common strategy among the workers is to try to build a stable "wall" of heavier, regular-shaped and stable parcels in the front and back of the cage. By doing so the parcel tends to stay in place and not fall over when the gate opens up at the arriving terminal. If they save a space for a heavy parcel in the front end of the cage they can avoid reaching deeper into the cage with heavy parcels. This strategy usually starts with filling the back of the cage (furthest in) with parcels up to approximately half the cage. By doing so they have the possibility of stepping into the cage, not needing to reach far in and bend the back as much.

"Layer by layer" Another way of thinking is to start with the bottom layer, using the entire space, and building layer for layer up to approximately chest-level. Thereafter the workers places the parcel furthest in to the cage all the way up and thereafter places the parcels layer after layer towards themselves.

4.1.3.2 Harmful behaviour while packing

In the qualitative study at the terminals different behaviours that in one way or another may be potentially harmful for the workers were observed and identified. Three behaviours were analysed to understand the underlying reasons, the risks with them and what can be done instead/how those behaviours could be improved. The

entire analysis is found in Appendix D, and a summary of the findings can be seen below.

1. Packing parcels above a non-foldable gate A normal step when packing parcels is to put a gate on the cage while packing to make sure the parcels will stay in place. The cage can be more or less packed when the worker chooses to put on the gate using either a foldable or non-foldable gate. This risk occurs when the worker puts on a non-foldable gate and continues to put parcels into the cage afterwards by putting them above the gate (the height is approximately 2 m above the ground). Figure 4.5 presents an illustration of how this behaviour has been observed. Reasons for the behaviour can be to avoid extra work of re-packing the parcels if they should fall out on the floor, and to avoid getting injured if that would occur. The behaviour affects the workers' risk for physical overload and injuries due to very high lifts over the gate. It also increases the risk of parcels falling from the cage in a later part in the process since they usually have not been placed stably. If the worker would use a foldable gate it would be easier for him/her to pack parcels stably and it would decrease the ergonomic risk of injuries and overload.

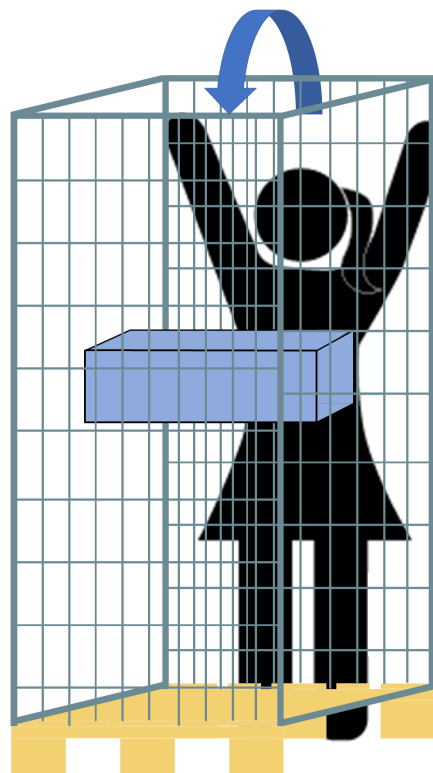


Figure 4.5: An illustration of how packing parcels above a non-foldable gate could be done.

2. Ski-slope building of parcels The ski-slope building of parcels occurs when the parcels are packed from the furthest in of the cage and towards the worker in a way that next layer of parcels are not able to fit the entire area of the cage, in the end resembling a ski-slope. This behaviour is common among new or inexperienced workers with lack of knowledge of how to pack a cage optimally, often with a combination of being under time pressure. The ski-slope building makes it easier for parcels to fall inside the cage leading to higher risk of parcels falling at later stages in the process. Poor utilization of the cage also results in higher costs due to more cages needed for transportation. To avoid this behaviour the workers need to have enough knowledge of how the situation can be prevented, with different strategies of how to pack parcels into a cage. When the workers experience stress such knowledge might be forgotten due to other things drawing their attention, like catching up with the work.

3. Re-packing of parcels Re-packing of parcels in the cage occurs due to different reasons. One being a new parcel fitting better into a space in the cage than the previous one due to external reasons like weight or size of parcel. Another reason is that the new parcel cannot be packed into the cage due to its characteristics or if it does not fit the worker's packing strategy, e.g. heavy parcels in the bottom of the cage. In such cases the already placed parcels in the cage need to be placed somewhere else or left outside the cage until a suitable place occurs. Reasons behind this behaviour is to enable more optimal utilization of the cage or a more stable packing to avoid falling parcels later in the process. Re-packing leads to more lifting for the worker, affecting the physical ergonomics. Sometimes it can be better for the worker to start packing in a new cage instead of re-packing an old one, depending on the possibility for this and the specifics of the parcel (e.g. heavy and large parcel).

4.1.3.3 Anthropometry

The current packing height ranges between 144 mm (the height of the EUR-pallet) to 1944 mm, which indicates a wide range in height for the workers when packing the parcels inside the parcel-cage. To understand the current physical ergonomics risks for the workers it is crucial to understand which heights are acceptable or unsuitable to lift a load within. According to the SWEA, manual handling of weights or loading should not be done with the hands above shoulder height or lower than knee level [8]. The OSHA in the United States is another administration that mentions the so called "Power zone", that is the optimal zone when lifting loads, to be between mid-thigh to mid-chest with the load close to the body [27]. It is, therefore, crucial to understand the proportions between the acceptable and unsuitable lifting height of the current parcel-cage.

For an inclusive design it is important to consider different critical users. Since height is a very important factor in this case, people of different lengths will be considered. Different anthropometric measures are used to find the optimal height

interval when sorting parcels into the cages dividing the cage into three zones: Low, Medium and High. The design principle used for deciding the different heights of the zones is to rule out the extremes with approximately 90 % of the Swedish work population taken into consideration. The shoulder height of 5th percentile of women sets the upper limit of the Medium zone and the knee height of 95th percentile of men sets the lower limit of the Medium zone, according to Figure 4.6 where the different zones are illustrated for the current parcel-cage. The Low zone is defined as everything below 508 mm, Medium zone: 508-1255 mm, High zone: >1255mm.

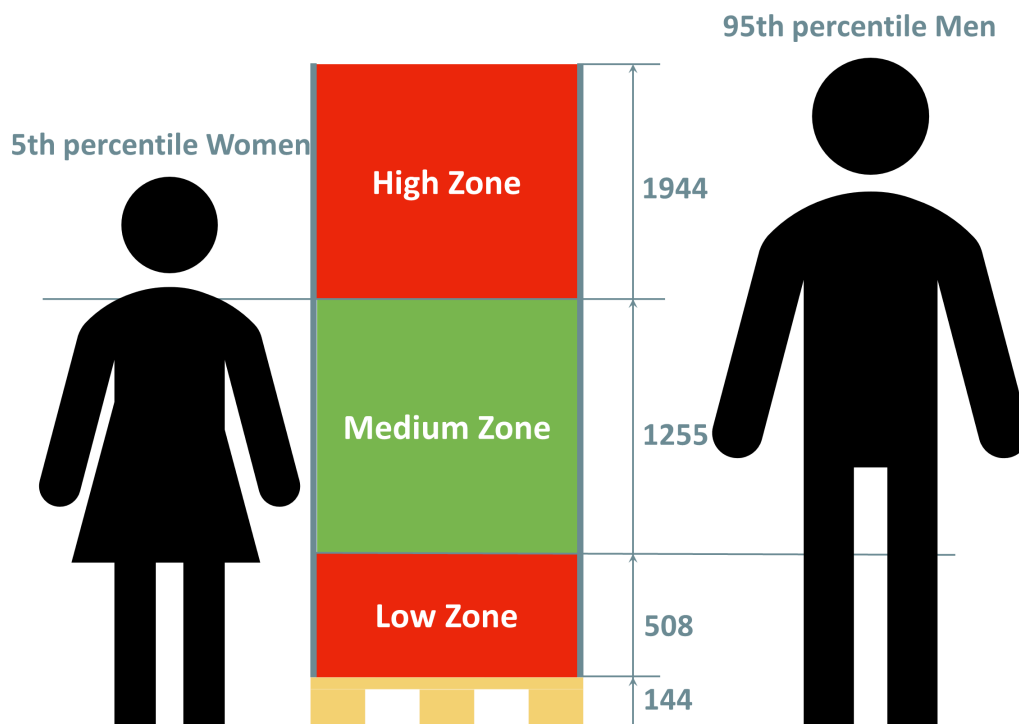
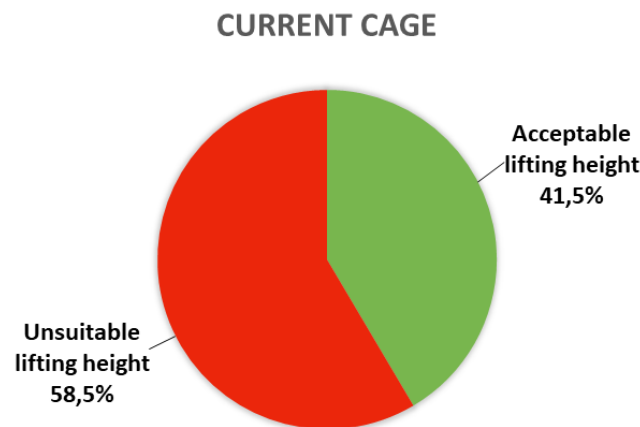


Figure 4.6: Heights of current parcel-cage with the three zones, Low, Medium and High.

Calculating the percentage of the acceptable (medium) and unsuitable (low and high) zones for the parcel-cage provides a good approximation of the current physical ergonomics risk. The proportions are presented in Table 4.5 and Figure 4.7. The calculations indicates that 41,5 % of the cage is in an acceptable lifting height for approximately 90 % of the Swedish population. The unsuitable height zone considers both the low and high zones with a result of 58,5 %.

Table 4.5: Percentage of Low, Medium and High zone in the current parcel-cage.

Height interval	Percentage
Low: <508 mm	20,2 %
Medium: 508-1255 mm	41,5 %
High: >1255 mm	38,3 %

**Figure 4.7:** Percentage of acceptable and unsuitable lifting heights for the current parcel-cage.

4.1.3.4 Cube model

Different situations occurring when packing parcels into cages will be evaluated with the Cube model. The Cube model considers three factors: time of the work task, force (weight) of the parcel and posture of the worker. To evaluate the work task in a general way the factors will be analyzed and assigned a severity level using criteria from the provision of SWEA. Analyses of the factors are based on result from the qualitative study.

Posture The posture aspect is connected to where in the cage the parcel is put. Different zones in the cage are compiled from anthropometric measures, see Figure 4.5. These measures are used to divided the cage into three different height zones: Low height: <508 mm, Medium height: 508-1255 mm and High height: >1255 mm.

Since the Cube model was developed to classify and analyse work done with the use of hand tools, it is complemented with inspiration from a model for estimating working postures for the entire body in a standing/walking position from the SWEA's provision 2012:2 [8]. By using this model as inspiration when deciding the different severity levels in the posture interval a more correct evaluation can be done.

The work postures for the different zones were evaluated through the model to see whether the posture is acceptable, should be evaluated more closely or if it is inappropriate. The severity level of each height zone will be rated depending on how the resulting posture is evaluated by the model. If the posture is acceptable it will receive a 1, needs further investigation a 2 and inappropriate a 3. To understand which interval the work posture for the different zones is within, a closer evaluation of how the neck, back, shoulder/arms and legs are located for each posture is made. A summary is presented in Table 4.6. For further motivation of the result, see Appendix E. The aspects looked at more closely are for example whether the body part is bent, twisted, has a low degree of freedom, is below or higher than a point on the worker's body or if there is sufficient place to move the body. The aspects are classified according to how often they occur for the specific height zones. It distinguishes between if they happen to a significant extent (often) in the work, periodically (sometimes) or rarely. The Low and High zones were both regarded as inappropriate, thus obtaining a level 3 in severity. The medium zone was regarded as a zone to investigate more closely, thus a severity level 2.

Table 4.6: Summary presenting how often each risk occurs regarding posture aspects: to a significant extent (S), periodically (P) or rarely (R). Adapted from [8].

	Neck			Back						Shoulder/Arms						Legs		
	<i>Bent or Twisted</i>			<i>Bent or Twisted</i>			<i>Low degree of freedom</i>			<i>Below knee or above shoulder height</i>			<i>Outside 3/4 arm distance away from torso</i>			<i>Insufficient space</i>		
	S	P	R	S	P	R	S	P	R	S	P	R	S	P	R	S	P	R
Low Zone	X			X				X		X				X			X	
Medium zone		X			X			X				X		X			X	
High zone	X				X			X		X				X			X	

Force The SWEA suggests that the maximum load to handle is 25 kg in most cases [8]. However, the distance of the load from the lumbar spine is also an important factor to consider where 25 kg is the maximum weight when having the parcel within the underarms length (i.e. close to the body) [8]. Observing the worker's behavior when sorting the parcels, their arms were seldom within the distance of the underarms, thus more likely within the area of three-quarters of the arm length (mixed with bending the back forward to reach in the parcel-cage). The SWEA has developed a model in provision 2012:2 for evaluation of lifting that takes the distance the weight is away from the lumbar spine into consideration, see section 2.1.3.2 [8]. Corresponding to the postural ratings, the weight intervals chosen was from the model are; Low weight: 0-3 kg, Medium weight: 3-15 kg and High weight:

15-30 kg. The different weights are given a severity number, starting with least severe (1) for the Low weight going up to the most severe (3) for the High weight.

Time The time aspect is connected to the total time the work task of packing parcels into a cage is conducted for a worker during a workday, and how repetitive the task is. Concerning the time aspect, the body needs to get enough recovery and rest in between the loading of the body tissues [6]. According to the SWEA repetitive work is when one or few work tasks are done to a large extent of the working day, normally with a high tempo [8]. The worker's main task when packing parcels into cages is to move the parcel from the outline (a table in fixed height) to the correct cage and when the cage is full, close the parcel-cage by putting on a gate.

The frequency of work is dependent on the number of parcels sent during the time period. This can differ a bit depending on when in the year and week it is but the work rate is fairly similar over the day. The sorting of parcels ends when all the parcels are sorted or at a specific deadline-time when they have to be finished. Due to very time-restricted schedules, they have to leave the rest of the parcels to the next day if they are not ready with the sorting before the deadline-time. It is very important to follow the time schedules for the trucks, so as not to delay the entire chain.

To evaluate if a work task is repetitive, the SWEA's model for evaluating repetitiveness in provision 2012:2 is used, see section 2.1.3.3 for more theory. The model considers four aspects: the work cycle, work posture, work pace and work content [8]. To define how repetitive the investigated work task is, the different aspects were evaluated for the large-sized terminal and the medium-sized terminal to be able to set a severity level on the time criteria. The packing of parcels into cages is conducted at the departing terminal, thus the description below is for these terminals as well.

The large-sized terminal

At the large-sized terminal, the workday of 8 hours is divided into 3 phases for the full-time workers. The first phase is preparation before production starts where several different work tasks in general are conducted. The second and third phases are both approximately 3 hours long and consist of different work tasks connected to the production and after production. Normally, a team leader tries to rotate the type of work the workers do in between the shifts, especially if the worker has been packing parcels into cages, since this is a heavy work task physically. Sometimes the team leader cannot assign workers to different types of work tasks, but they can change in between the work station (e.g. a worker can be assigned to sorting parcels to other districts).

The medium-sized terminal

At the medium-sized terminal, the workers handling the parcels during the departing shift work 4 hours per day. To vary the worker's tasks they have half an hour

each day working at the groupage department, transporting groupage with a forklift. The other 3,5 hours are spent rotating between putting the parcels on the conveyor belt and sorting the parcels in cages, spending approximately half the time at each station.

Evaluation of the time-factor

Packing parcels into the cages is done repeatedly in very short time-intervals when the worker is at a specific work station. The terminals have different prerequisites due to the size of the terminal and they therefore also have a difference in work rotations for the workers. The large-sized terminal rotates more between different work tasks, although they have longer workdays. The workers at the medium-sized terminal can alternate between the work tasks in the parcel process to a higher extent. The work postures are described in more detail and analyzed deeper in section 4.1.3.4 but can in brief be described as workers having restricted possibilities to influence how the work task is done. The work pace is set either by the worker/workers putting the parcels at the conveyor belt or by the maximum pace the conveyor belt can transport the parcels. Normally the work pace is relatively high making it difficult for the worker at the outlines to work in his/her own work pace. There are different types of conveyor belts used at the terminals. One type is only able to transport the parcel from the start of the conveyor belt to the different outlines, but will stop if the outlines are full with parcels. Another type enables the workers to continue putting parcels on the conveyor belt due to the conveyor belt being a continuous loop, enabling parcels to go around even if the correct outline is full. When one outline is full of parcels the parcels will either continue around on the conveyor belt or stop the belt entirely. Because of the work rotation the workers conduct a few or several work tasks in the production process during a shift. Using the SWEA's model presented in section 2.1.3.3 the time aspect is considered to be a consistent overall medium risk, thus a severity level 2 is given when conducting the Cube model evaluation.

Compilation of limit values and severity levels for the factors The value limit and severity levels for the factors posture and force are compiled into Table 4.7. The time factor is considered as constant with a severity level of 2 based on the reasoning above.

Table 4.7: Compilation of limit values and severity levels for the Posture and Force factor.

Posture		Force	
<i>Low zone:</i>	Definition: <508 mm	<i>Low weight</i>	Definition: 0-3 kg
	Severity: 3		Severity: 1
<i>Medium zone:</i>	Definition: 508-1255 mm	<i>Medium weight</i>	Definition: 3-15 kg
	Severity: 2		Severity: 2
<i>High zone:</i>	Definition: <1255 mm	<i>High weight</i>	Definition: 15-30 kg
	Severity: 3		Severity: 3

Result - Cube model evaluation The different factors are combined to create different possible work situations. The situations are evaluated with the Cube model to identify which situations creates the worst physical ergonomics risks for the workers. Nine different situations can be combined and the result is presented in Table 4.8. The risk rating is provided to the right in the table and ranges between 1 to 27 with a higher number meaning a more harmful physical loading of the body. The riskiest situations regarding injuries and overloading are the red ones and they are described further below.

Table 4.8: Physical ergonomics result from Cube model evaluation.

Combination	Posture	Force	Time	Risk number
<i>Alt. 1</i>	Low zone	Low weight	-	6
<i>Alt. 2</i>	Low zone	Medium weight	-	12
<i>Alt. 3</i>	Low zone	High weight	-	18
<i>Alt. 4</i>	Medium zone	Low weight	-	4
<i>Alt. 5</i>	Medium zone	Medium weight	-	8
<i>Alt. 6</i>	Medium zone	High weight	-	12
<i>Alt. 7</i>	High zone	Low weight	-	6
<i>Alt. 8</i>	High zone	Medium weight	-	12
<i>Alt. 9</i>	High zone	High weight	-	18

In the Cube model evaluation, low and high zones of the parcel-cage have the same and highest severity level since they both are zones within a unsuitable lifting height for the workers. In combination with the high weight of the parcel (>15 kg) these situations are the riskiest with regard to the physical loading of the body. These situations are followed by medium-weighted parcels (3-15 kg) in the same unsuitable lifting areas. The medium zone, which is at the acceptable lifting height, can also involve some bad physical loading situations, mainly when the parcels are heavy.

4.1.4 Tracking system

In this chapter identified reasons why a shortage of cages occur will be presented together with an evaluation of the current tracking system. A description of how the current tracking system works is found in section 1.1.2.

4.1.4.1 Shortage of empty cages

Two kinds of shortage could occur in the parcel-cage process: a long-term and a short-term shortage. The long-term shortage has to do with a lack of knowledge of where the cages are located, i.e. the disappearance of cages in the system. The short-term shortage of cages has to do with terminals not having enough cages for daily production, thus needing to use extra cages made of corrugated cardboard.

As mentioned in the problem definition, a shortage of cages can lead to decreased productivity in the whole process. To avoid a shortage of cages it is important to first understand why it occurs. From the qualitative study, several reasons were identified as to why a shortage occurs. The reasons can be divided into a variation of production and low control of where the cages are located, as described below.

- Variation of production
 - Uneven flow of parcel-cages
 - High parcel volume on the roads
- Lack of control of where cages are located
 - Cages are used in alternative flows
 - Stock of empty cages at terminals

Uneven flow of parcel-cages The uneven flow of parcel-cages occurs when a terminal sends more or less cages than they receive from other terminals. The terminal can either end up with more cages than they send away, or less, creating an unbalance in the system. External reasons such as whether the district is in a producing area with many industry companies, or in a consuming area with a lot of parcels being received to the area, can affect this. The uneven flow is a reason why empty cage transportation is needed between terminals.

High parcel volumes on the roads When there is a high volume of parcels on the roads between terminals in Sweden, there is also a high volume of parcel-cages which means fewer empty cages available to use for the entire system. This occurs especially when there is a high season for parcels, as explained in section 4.1.2. On the contrary, when there are low volumes of parcels sent there is an overflow of cages at the terminals.

Alternative flows The intention of the parcel-cage is for transportation of parcels between terminals. However, other alternative flows exist that are either known or unknown. When the cages are used in alternative flows there is no/less registration and less control of the cages since no clear routines exist.

An example of a known alternative flow is within the network and distribution area when the cages are transported back and forth to customers with special agreements. The customers are in need of cages to easily transport the parcels with DB Schenker. They report to the terminal within their district how many cages they need within a time period, for example 30 cages/week or 5 cages/day. According to the interviews, the customers tends to overestimate (by purpose or inattentively) the number of cages they need to be able to transport their parcels. It is also known that the demand for parcels varies over the year, and therefore also the parcel-cages. No registration of cages is done for these alternative flows, which means a lack of knowledge of where the cages are. There is therefore no way of knowing if the right number of cages are transported back to the terminals or where they end up. The

flow of cages going back and forth to customers is described as a "self-playing piano" happening in good faith. At the same time, the interviews indicate that customers can have a large number of empty cages in their "backyard" or possibly use the cages for other purposes. If the cages are not clearly marked with Schenker's name it could be difficult for larger companies to differentiate Schenker's cages from other logistics company cages.

Stock of empty cages at terminals Regular inventories of how many empty cages each terminal has in stock is a standard work task currently conducted every other week. According to the study, many workers believed that not all terminals register the correct number of how many empty cages they actually have at their terminal, the reasons being many. One of the reasons could be that the empty cages might be at places in the terminals that workers are unaware of. The current way of handling empty cage transportation is insufficient, which makes it difficult for the workers at the terminals to trust the system. This could be one reason why the workers choose to keep a higher stock of empty cages at the terminals than needed since it could be their way of ensuring they will not be short of empty cages.

4.1.4.2 Evaluation of current tracking system

This section presents the evaluation of the current tracking system for the cages; the Cage flag, the Cage app and the cage registration. Some of the problems found in the evaluation will not be investigated further in this project, however, they are presented in Appendix F.

Cage flag The worker's general opinion is that the Cage flag is a good and easy way to know the end destination of a specific parcel-cage. However, some problems can occur when the Cage flag is not handled as intended. This finding will not be used in the continuation of this project, but the details can be found in the general evaluation of the current tracking system, see Appendix F.

Cage app One of the purposes of the Cage app is to gain knowledge of how the cages are transported between terminals today and how it affects the number of cages existing at each terminal after the daily transportation is done. The registration of cages in the Cage app is done by the terminal workers in the departing terminal. The terminal worker manually scans the Cage flag connected to a specific cage to register it as on the way to the arriving terminal. In section 1.1.2 the current tracking system of the cages is described in further detail. The Cage app compares the sent number of cages from a terminal with the received number to get a balance score of how many cages the terminal will end up with after the daily production. The balance score is either positive if the terminal receives more cages than they send, or negative if they have fewer cages at the end of the production day. The

daily balance of cages for each terminal is thought to provide knowledge of how the empty cage transports should be done to avoid a shortage of cages.

The workers at the terminal currently use experience, routines or incoming requests by emails from terminals in need of cages to know where they should send empty cages. If a terminal has too many empty cages they can either send the cages directly to a terminal in need, have them in stock at their terminal or send it to the hub in Jönköping that has the responsibility of distributing them to the terminals in need. The Cage app is currently used at the terminals when the terminal worker scans the Cage flags. However, the knowledge that could be gained from this system is currently not used by the two terminals that the qualitative study for this project was conducted at. Thus, team leaders and terminal managers consider the system to take time from terminal workers in the production without offering any helpful knowledge back to the workers. Possible reasons why the workers are not using the Cage app in the way it is meant to be used are described further below.

The inventory part of the Cage app is not used today, but is thought to provide another way (than the existing one) to report the number of cages (stock level) at the terminals.

The Cage app data is not as trusted as other systems the workers at the terminals use and they address the uncertainty of whether the data is correct or not. One of the terminals has had problems with their servers making them unable to scan the Cage flags, thus the data was not correct during this time. It is crucial for the data for all terminals in Sweden to work as it should. Since it is a rather new system the implementation time could affect the correctness of the data in some cases.

Another reason that was identified in the qualitative study was the lack of knowledge of what the system could contribute to and how it could be helpful for the team leaders and terminal workers. Not knowing what knowledge the system could provide makes it hard for the team leaders specifically to take the time needed to understand how the information could be retrieved and used. A type of information that could be provided is the number of cages that are on the way to the arriving terminal, but the team leaders argue that they have other systems they use for gaining the information of how large parcel volumes are on the way to the terminal (for being prepared).

Cage registration Today the registration of how many cages are being transported between the terminals is done in two different applications, the Cage app and the transportation documents registration (connected to the Qlikview application). The applications are used for different purposes where the Cage app is supposed to be a helping aid for the terminal workers and the transportation document registration is used to pay the contract haulage companies the correct amount and for statistical reasons. For the cage app, the terminal worker manually scans the Cage flag in the app collecting information about the cages from all terminals.

The terminal workers also take notes of how many cages are going to be transported to each terminal and register them when writing the transportation document on the computer and giving it to the truck driver. This information is collected in a database connected to the Qlikview application. The truck drivers know how many cages they are going to transport and can therefore double-check if the number of cages is written correctly. Even though the systems are used for different purposes it takes extra time to conduct two work tasks instead of one, resulting in more time spent on cage registration for the current process.

4.2 New solution

The new solution consists of an optimal cage size and a tracking system described further in this section. The solution proposed is defined/explained and evaluated for both tracks.

4.2.1 Optimal cage size

To optimize the load factor in the truck the normal inside height of the linehaul transportation carriages (3,1 m) and the bar height (9 cm) was investigated to find the optimal cage size. Bars are currently used when transporting different sized groupage to utilize the space inside the carriage in a better way. They enable groupage to be loaded in different levels vertically. The base of the cage (width and depth) remains the same due to easy transportation with forklifts and common EU-regulations of the size since the cage is standing on a EUR-pallet which the carriage's width and length are based on. The idea of the new parcel-cage is to stack one cage on top of another using bars inside the carriages. Figure 4.8 illustrates how the new cages can be placed inside the carriage with the view from the back.

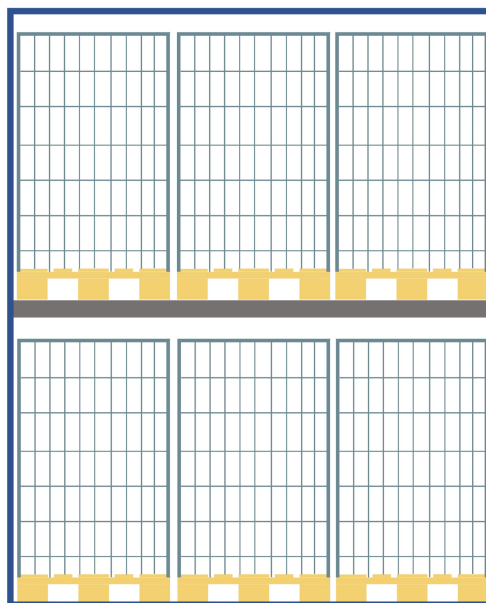


Figure 4.8: Illustration of how the new cages will be placed in the carriage.

The bars are normally fixed in the ceiling of the carriage until they are going to be used. When using the bars, the truck driver uses an equipment-stick to pull down one side at a time of the bar. In Figure 4.9, one of the bars is pulled down in a

carriage. When transporting goods and cages two bars are used, one in the front end of the pallet place and one in the back end.



Figure 4.9: A bar is pulled down inside a carriage.

To find the optimal height for the cage, calculations were done with respect to the inside height of the carriage and the bar-height, resulting in a maximum height for the inside of the parcel-cage (without margin included), see Table 4.9.

Table 4.9: Result of calculations done to find the maximum inside height of a cage.

Measure	Normal carriage
Inside height [mm]	3100
Height without bars [mm]	3010
Maximum height of one cage [mm]	1505
Maximum inside height one cage [mm]	1361

Different inside heights of the cage were considered from the calculations of the maximum inside height. The two alternatives evaluated had an inside height of 1300 mm and 1250 mm respectively. The results of the calculations done for the two alternatives are presented in Table 4.11.

Table 4.10: Presents margin between upper part of new cage and ceiling/bar.

Measure	Alt. 1	Alt. 2
Inside height [mm]	1300	1250
Total height [mm]	1444	1394
Margin for one cage [mm]	6,1	11,1

The margin between the upper part of the cage and the ceiling/bar is important to take into consideration when choosing between the two cage sizes. The margin has to be enough for the cage to easily be loaded and unloaded on the carriage and for safe handling with the forklifts. Due to the construction of bars inside the carriage, the cage must have a margin to the ceiling of at least one bar to be able to load/unload the top cages. Figure 4.10 and Figure 4.11 shows how the bars are located in the ceiling of the carriage. For this reason, alternative 2 with an inside height of 1250 mm, is chosen as the optimal alternative cage since it has a margin of 11,1 mm which will allow the top cages to fit in above a bar.

**Figure 4.10:** Bars are located in the ceiling of the carriage when not used.**Figure 4.11:** The bars are located two side-by-side. Seen from the side.

An important part to control was whether the bars would be able to carry the weight of the new cage. The bars' limit weight is 1000 kg for three cages. This was calculated in a theoretical way and with tests conducted at the two terminals. The theoretical calculations were based on the average parcel weight for the two terminals and the average number of parcels per cage. Tests of the current parcel-cages' real weight when being transported were done and were then used to do calculations of the new cage by comparing the volume change. Both calculations indicate that

the new cage would be able to operate within the weight limit. The calculations and results are found in Appendix G.

4.2.1.1 Proposal of new solution

The size of the new parcel-cages is defined below. The size difference will affect the current parcel-cage process. How many parcels per cage the new cage can transport on average and how many more cages will be needed in the process are calculated below.

Parcel-cage's size From the calculations above, the new parcel-cage's size is chosen to have an inside height of 1250 mm and a base of a EUR-pallet (800 mm x 1200 mm). The new parcel-cage's height is compared with the current cage in Figure 4.12.

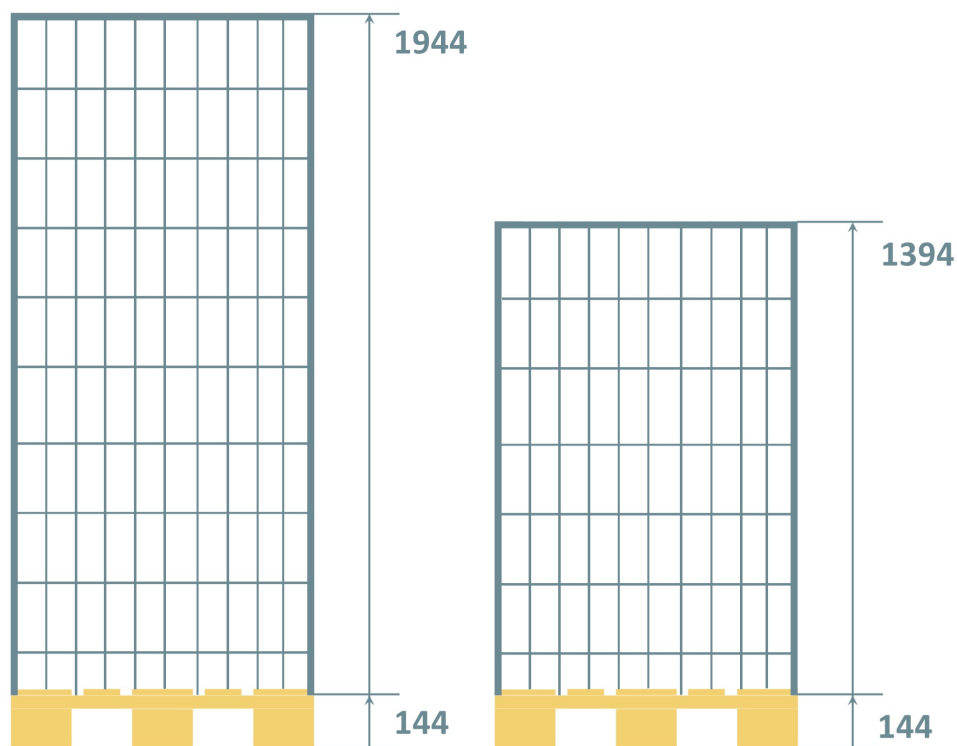


Figure 4.12: The current parcel-cage's size is shown to the left and the new parcel-cage's size to the left.

Average number of parcels per cage The average number of parcels per cage is calculated by taking the inside volume of current and new cages into consideration. The current average is calculated in section 4.1.2 to be 49,6 parcels per cage. Table 4.11 presents the calculation results showing that the new parcel-cage can transport 69 % of the current parcel-cage number, as a result of the volume difference. This indicates that the average number of parcels per cage for the new solution is 34,4 parcels/cage.

Table 4.11: Presents how many parcels per cage the new cage can transport.

Measure	Current cage	New cage
Inside height [mm]	1800	1250
Inside volume [m ³]	1,728	1,2
Difference compared to current parcel-cage [%]	1	0,69
Parcels/cage [pcs]	49,6	34,4

Number of cages needed Due to the lower number of parcels each new cage can transport on average, more cages will be needed to transport the same volume of parcels. According to the calculations, see Table 4.12, 44 % more cages need to be used.

Table 4.12: Presents how many more new cages needed for the same number of parcels as currently (percentage).

Measures	Current cage	New cage
Inside volume [m ³]	1,728	1,2
Percent cages needed [%]	100	144

Average number of parcels per pallet place Since the new parcel-cage can transport two cages per pallet place it is important to investigate how many parcels can be transported per pallet place. In Table 4.13 this number is presented together with the load factor for the current and new cage. The new cage has the potential to transport 68,8 parcels per pallet place compared to the current cage that can transport 49,6 parcels per pallet place. The load factor of the carriage is 89,9 % for the new cage.

4.2.1.2 Consequence analysis of change in handling of cages

The areas evaluated in the consequence analysis are the transport efficiency and environmental aspect, time for handling the cages and physical ergonomics. These areas are the most relevant and comparable in this case. The consequence analysis

Table 4.13: Comparison of average parcels per pallet place and load factor for the current and new cage.

	Current cage	New cage
Parcels/pallet place [psc]	49,6	68,8
Load factor [%]	62,8	89,9

in its entirety is found in Appendix H.

Transport efficiency and environmental aspect According to calculations done in section 4.2 the current cage can transport on average 49,6 parcels per cage while the new cage can transport 34,4 parcels per cage. However, the new parcel-cage height allows two cages to be stacked on top of one another, utilizing more space in the carriage as illustrated in Figure 4.13. This leads to a total of 68,8 parcels per pallet place.

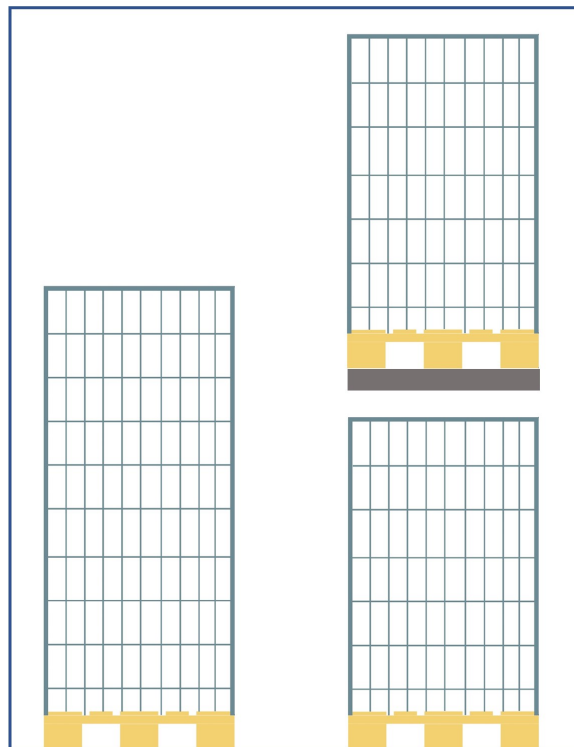


Figure 4.13: Illustration of how current cage is transported in carriage today (left side) and how new cage could be transported in future with bars (right side).

The load factor is calculated by dividing the used volume per pallet place of the two cages with the available volume per pallet place and is presented in Table 4.14 to be 89,9 % for the new cage.

Table 4.14: Result of load factor calculations for the new cage.

	New cage
Used volume per pallet place [m ³]	2,68
Available volume per pallet place [m ³]	2,98
Load factor (used volume/available volume) [%]	89,9

A large part of the environmental aspect for a logistics company has to do with the transportation of the goods with vehicles. The result of the transport efficiency indicates that more parcels would fit per pallet place for the new solution, thus a smaller footprint is needed for transportation of the same volume of parcels, meaning that fewer trucks would theoretically be needed. This indicates an opportunity to reduce emissions for the transports, which would have a positive impact on the environment.

Time of handling cages In the description of the new solution, see section 4.2.1.1, the proportion of additional cages needed for the new solution to transport the same volume of parcels as the current solution is calculated to be approximately 44 %. Some work tasks within the production will be affected by the increasing number of cages needed. In Figure 4.14 the sub-goals affected by the extra time required for handling cages are marked with yellow, orange or red. The colors indicate how critical they are for the parcel production to continue without any stops, yellow being the least critical and red the most. The criticality is based on estimations and takes into consideration when in the parcel production the work task is done, who is conducting it and how the work task is done. Conducting a work task during production is more time-critical than conducting it before the production start. Loading and unloading cages can be done both by truck drivers and terminal workers. Depending on who is doing the work task it affects the parcel production in different ways. The terminal worker is able to help in the production, while the truck driver is not.

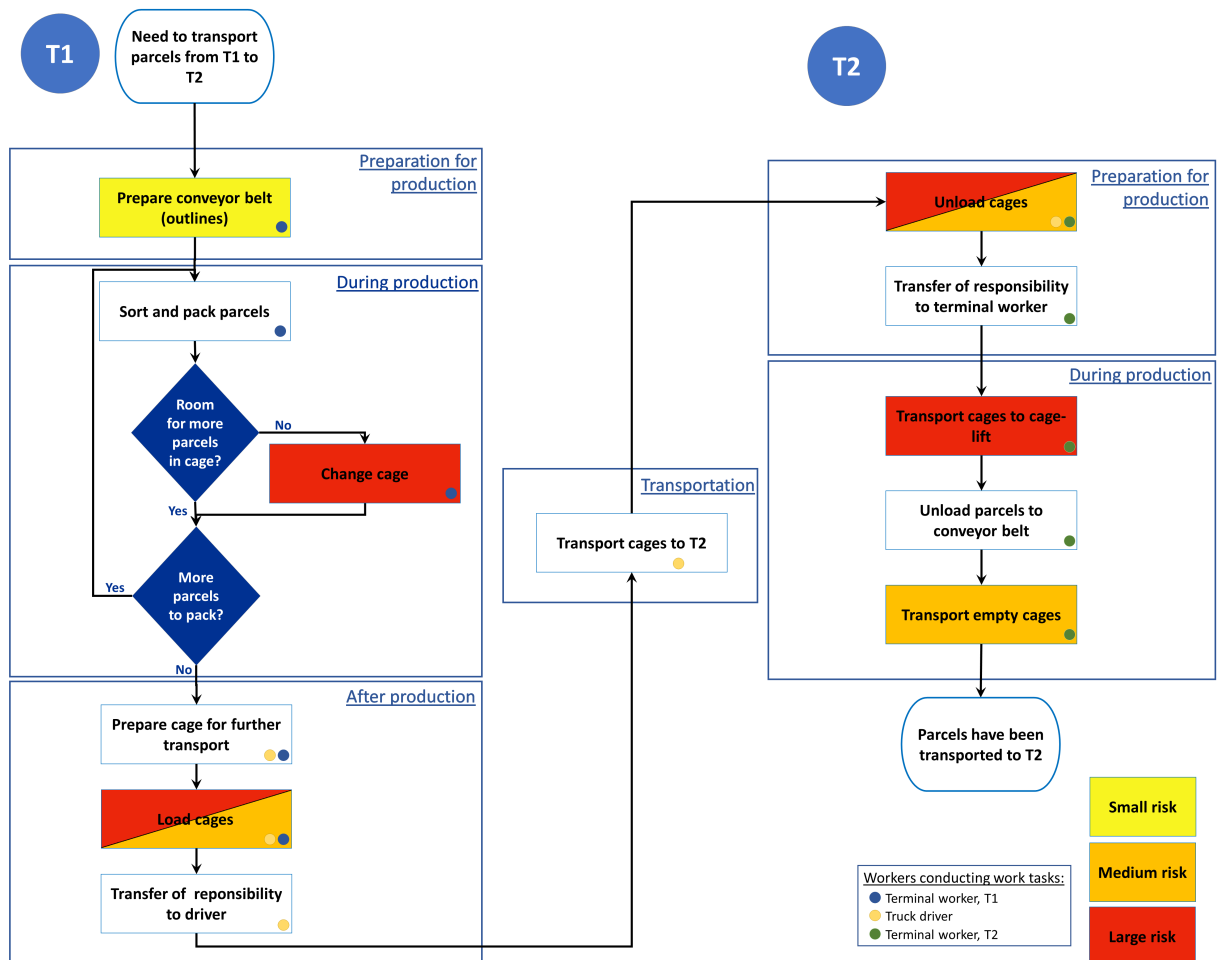


Figure 4.14: Sub-goals affected by the time factor are colour-coded at three different risk levels.

Physical ergonomics The lower height of the new cage, compared to the current cage, will lead to changes in the physical ergonomics risk levels for some work tasks in the parcel-cage process. The work tasks affected ergonomically by the change are presented in Figure 4.15, and consist of sorting and packing parcels into the cage, closing and opening the cage with the gates and unloading parcels from the cage. Figure 4.16 presents the new cage's three lifting and packing zones and how the acceptable and the unsuitable lifting height will be for the new solution. A lower height when putting on and taking off the gates also indicates better ergonomics since the worker can have their hands at a lower level. The height change also indicates that parcels would fall from a lower height, if they do so, when removing the gate and unloading parcels to the conveyor belt.

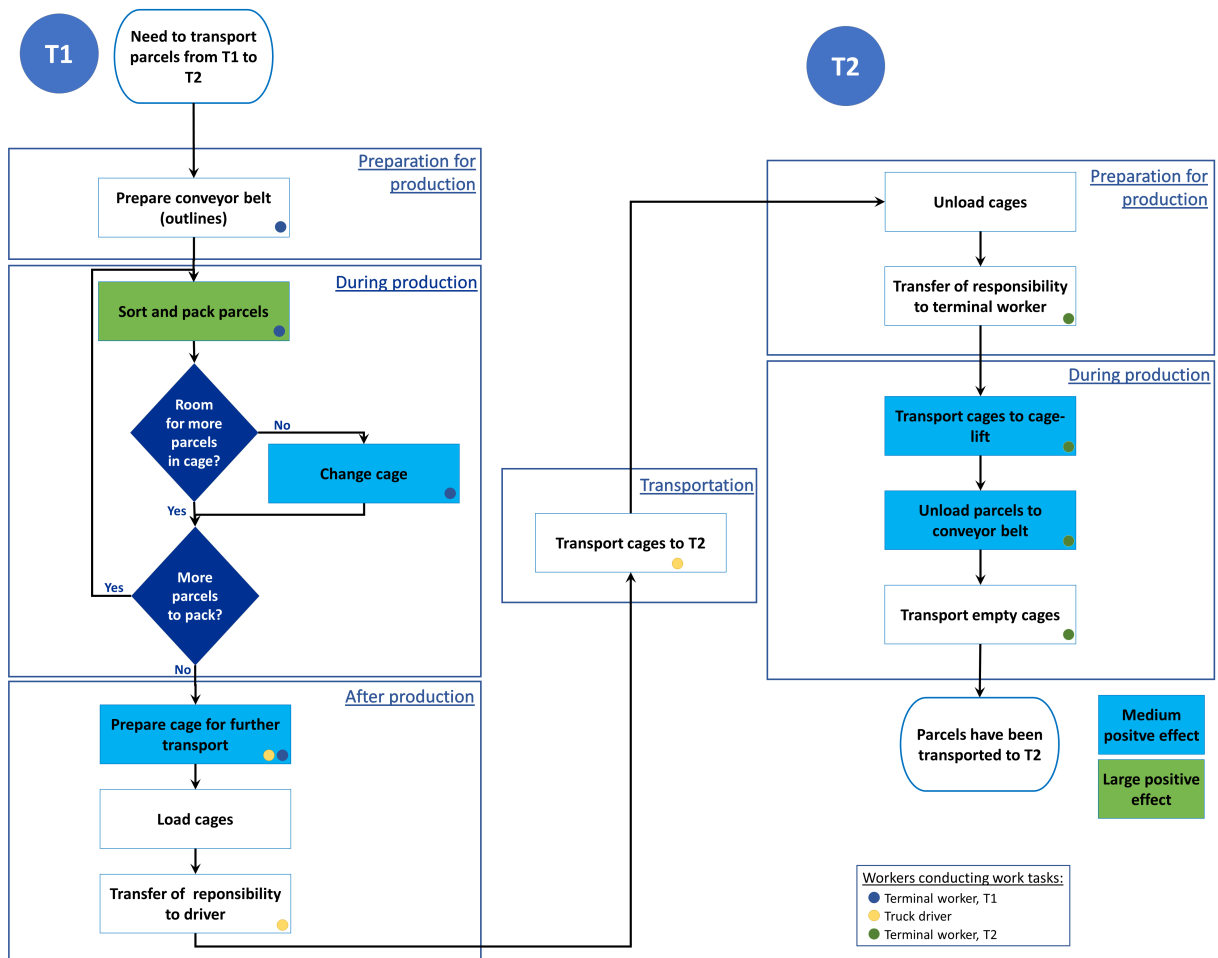


Figure 4.15: Sub-goals affected by the physical ergonomics factor are colour-coded with two different effect levels.

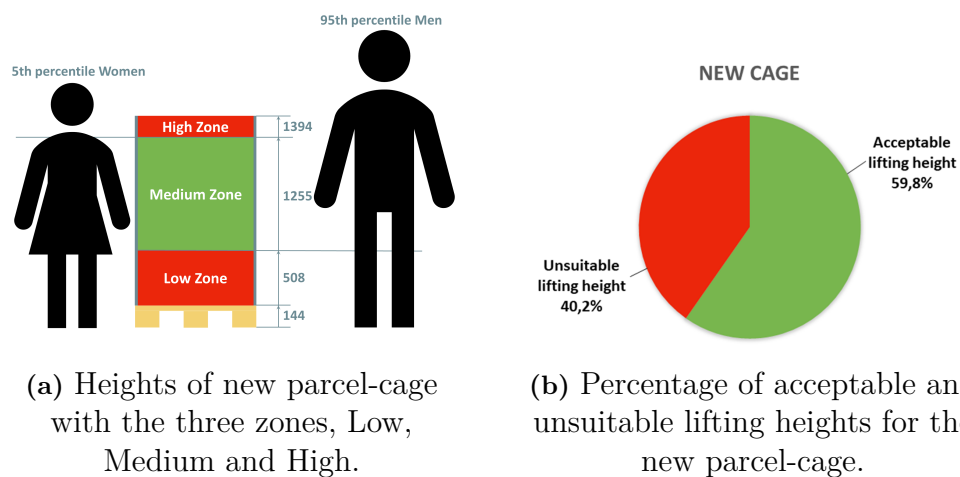


Figure 4.16: New parcel-cage's zones and percentage of acceptable and unsuitable lifting heights.

4.2.2 New tracking system

The new tracking system is presented below starting with the goal of the system and the available technology. The technology is then further investigated and more information regarding the chosen technology is presented. After this, how the new tracking system can be implemented and used in the future is evaluated.

4.2.2.1 Goal with tracking system

The new tracking system has two main goals connected to the reasons behind shortages of cages in the current process, as identified and explained in section 2.2. The low control of cage location affects the long- and short-term shortage. One goal is therefore to gain better control of where the cages are to avoid a shortage of cages and reduce losses. Having a system that could provide more specific cage-level information would enable knowledge of where the cages are located (or where their last location was). The variation of production is natural in the logistics business area, both when it comes to daily variation and variation over the year. However, variation makes it harder to get the correct knowledge of how to transport empty cages to avoid a shortage of cages in the short term. The other goal with the new tracking system is therefore to facilitate how empty cages should be transported between terminals to avoid a shortage of cages on a daily basis. This can be done by providing knowledge of how cages are transported between terminals, thus enabling the production to run as efficiently as possible.

4.2.2.2 Technology for tracking systems

There are different tracking technologies on the market today to track different products and parts. Some common technologies include GPS, GMS, RFID and barcode tracking as described in section 2.2. To understand how a tracking system can contribute to reducing losses, a suitable technology for tracking cages is selected and further investigated below.

One goal of the tracking system is to gain better control of the cages by having tracking on cage-level. The linehaul parcel-cage is an internal product transported within Schenker's organization. The terminals at different geographical places in Sweden are still within the company. Outdoor positioning technology is commonly used for outbound logistic systems between different companies since it is an easy way to know where the products are located without implementing a massive system for all companies [11]. Indoor positioning systems are often used in so-called indirect distribution, i.e. internally at a company before it is sent away to the end location [11]. Since the parcel-cages have no defined "end destination" (since they go in loops between the terminals) they are located in an indirect distribution. They enable parcels to get to their end destination by transporting them through a part of the parcel process. This indicates that an indoor positioning system would be the best fit for the parcel-cage tracking system.

Real-time tracking systems reveal where the cages are located in real-time. Event-monitored systems track the last registration between the tag and a reader for the cage. The accuracy needed for the new tracking system is to know at which terminal the cage is located. The event-monitored system provides enough information needed and good accuracy with the possibility of identifying the last registration of the cage. Barcodes and RFID are two event-monitored systems.

The RFID system enables reading of the cage to be done without any human interaction because it is an auto-ID system and there is no need for a clear line of sight between the reader and the tag, it just needs to be within the reading range. The barcode system needs a clear line of sight between the barcode and the reader, implying a more time-demanding system than the RFID system.

From literature it is seen that RFID is a commonly used technology among businesses when it comes to inventory management and supply chain logistics [15], [28]. Zebst and Sower [16] conclude that RFID is used in many different business areas to be more competitive, increase performance and reduce costs within the organization. Efficiency can be improved through better accuracy in the process which would also lead to better quality in delivery [16].

Based on the literature study, RFID is evaluated to be a good choice for the new tracking system.

RFID system There are three different types of RFID technology existing today, namely active, passive and semi-passive [11]. The three types are described below and a summary of advantages and disadvantages is presented in Table 4.15.

Active tags

Active tags have their own battery (power source) making it possible for the tags to transmit data with predetermined time intervals, enabling higher-range communication [11]. The active tag can store more information than a passive tag but will have a shorter life-time due to this [16]. Since the active tags have a battery source they will be larger and heavier than the passive tag and more expensive [29].

Passive tags

Passive tags have no internal power source and are instead powered by the electromagnetic field from the reader when tag and reader are close enough [11]. When the tag is not within the area of a reader it does nothing, making it simple and inexpensive in comparison to the other types [29]. Other benefits are the longer life-time the device has and the physical benefit of being both smaller and lighter [11]. Although the passive tag can have different reading ranges depending on if the tag is read by low, high or ultra-high frequencies, it still has a shorter reading range than the other RFID types [29]. Passive tags are generally more robust and resistant to a harder environment than the other types of tags [29].

Semi-passive tags

The semi-passive tags can reach a higher range of communication than the passive tags due to their internal power source but still need to have a passive response from the reader [11]. Since the tag has its own power source it is less dependant on power from the reader (compared to the passive tag). For the passive and semi-passive tags, the antenna communicating with the tag is in the reader [29]. The range of how far away the tag can be from the antenna to transmit information is longer than the range needed for the tag to be sufficiently powered [29]. This means that a semi-passive tag with an internal power source can transmit information at a longer distance than the passive tag since the battery provides power for the signal to be transmitted. In other aspects, the semi-passive tags have similar pros and cons to the active tag but it is less expensive, has slightly higher life-time and shorter reading distance [29].

Table 4.15: Summary of advantages and disadvantages for RFID types.

	Active	Semi-passive	Passive
Reading distance	Longest	Medium	Shortest
Cost	Most expensive	Expensive	Less expensive
Life time	Shortest	Medium	Longest
Size and weight	Largest and heaviest	Medium large and heavy	Smallest and lightest
Robustness	Less robust	Medium robust	Most robust
Information storage	Highest	Medium	Smallest

Frequency interval

The second aspect when defining an RFID system is connected to which frequency the system should operate on. The reader can discover any tag within the correct distance with the same frequency as itself [15]. There are four different frequencies on which the RFID system can operate; low frequency (LF), high frequency (HF), ultra-high frequency (UHF) or microwave (MF) [15]. The different frequency intervals enable different reading ranges for the tags, where LF has the lowest range and MF has the highest, according to Tajima [15].

Justification of RFID system choice

With the lowest cost, longest life-time and smallest size, the passive tags are preferable over the others. The passive tags are also the most robust ones, which is favorable in the production environment they will operate in at Schenker. The information storage will be more limited than the other types of RFID systems, however there is no need for a large amount of information for the cages.

A passive tag operating at the Ultra High Frequency (UHF) is the most common choice for supply chain applications and inventory management since the combination provides a fair and sufficient read range combined with a low cost [15], [16]. Since the combination passive tag and UHF system is well-proven and popular it is chosen for the parcel-cage tracking system.

4.2.2.3 Explanation of new tracking system

The proposed new tracking system will consist of hardware (tags and readers) and software that connects all the information gathered from the hardware and other applications. The system will enable tracking at cage-level (by having a tag on each cage) to achieve better control of the cages and reduce the shortage of them. It will also facilitate empty cage transportation and reduced loss of cages by providing knowledge of how they are transported.

Inventory and control of cages Tracking at cage-level can be done by having an RFID-tag on each of the cages and one or several readers at each terminal. The tracking system will be able to know where the last registration of the cage is and thus which terminal is responsible for the cage. This will lead to better control of where the cages are and, if a cage disappears from the process, what terminal the last registration was made at.

The new tracking system could make an automatic inventory of the number of cages at each terminal. The last registration of the cage should indicate the terminal where the cage is located. To validate that the actual number of cages in the terminal and the automatic system's number matches a manual inventory can be done by the terminal workers with a handheld computer (working as an RFID reader). If the number differs, further investigations should be done. It could possibly be that a cage's tag stopped working and needs maintenance, or that the cage has been used for other purposes.

Cage registration As described in section 4.1.4 the cage registration is currently done with two separate work tasks, using the Cage app and writing the transport document (giving information to the Qlikview application). The information from the Qlikview application is currently more accurate than the Cage app since the system has been used for a longer time. The workers have a good routine on how the information is gathered, and the haulage companies get paid accordingly based on the information in the system, indicating that it is well trusted. The data from the Qlikview application can be used for the new tracking system to be able to provide knowledge of how the cages are transported between the terminals. By comparing the sent number of cages from a terminal with the received, a balance of how many excess or deficit cages the terminal will end up with after the daily production can be obtained, just like how the Cage app works currently. The cage balance score together with the current inventory level of empty cages will provide a presumed inventory level of how many cages each terminal has after the daily production. This indicates whether the terminal needs more empty cages or if they can send cages to other terminals.

Collecting the same information with two different methods takes more time than necessary, especially since this is done in connection with the parcel production.

The work task can be conducted before, during or after production, depending on the situation. The data used in the new tracking system should be from the Qlikview application since it is a more adapted system and used more widely in the organization. The tracking system can automatically collect the data of how many cages that are sent and to which terminals from the Qlikview application.

Implementation of tracking system in the process Correct implementation of hardware and software for the system is critical for the system to work as intended. The software system should provide information on where the cage's last registration was and how many cages are transported between the terminals daily. Implementation of the connection between the data in the Qlikview application and the tracking system needs to be done. Each cage will be provided with one tag that will register the destination of the cage when it passes a fixed reader at the terminal. The fixed reader will register the cage to the specific destination when the cage arrives at the terminal and passes the reader.

Tag implementation on parcel-cage

There is a large variety in RFID tags, both when it comes to function, form and usability. The RFID tag will be fixed onto one part of the cage. Normally the tags are used until their lifespan is over or until the part which the tag is on cannot be used anymore. The tag should be placed in connection to the logo plate or directly welded onto the cage net to be as robust as possible.

One important aspect to have in mind when deciding the optimal place for the RFID tag on the cage is that the cage consists of five parts that often are disassembled to fit into an empty cage for better space utilization when transporting empty cages. The cage consists of a EUR-pallet, two long sides and two gates (short sides), see section 1.1. That means there are two options of where to put the tag on the cage, either on the long side or the gate. When opening the cage, the gate is taken away to put in and take out parcels transported in it, thus this part is the most common one to be taken away from the EUR-pallet. Since it is handled more often, the gate has a higher risk of getting damaged which affects its lifespan. When assembling the cage, the minimum parts that are needed for it to work as a cage are both long sides and one gate together with the EUR-pallet. That means both gates are not required to be assembled for the cage to be able to be sent, which sometimes happens. When the cages are disassembled it is important that they are correctly assembled again so that only one tag will be on the cage.

Reader implementation Regarding the readers that will be fixed inside the terminal, it is important to analyze how the cages are transported from the carriage into the terminal to cover all used entrances with readers. Depending on the terminal layout different numbers of fixed readers might be needed to cover all possible alternatives. According to the qualitative study there are two different ways the cages are transported from the carriages to the parcel conveyor belt in the large-sized terminal, as presented with red arrows in Figure 4.17. One way is when the cages are arriving to the terminal in the groupage part of the building through an

opening in the wall. The other way is through gates close to the buffer of cages with parcels, on the way to the cage lift.

It does not matter if a cage is registered several times at the same terminal if it is moved around in the terminal. As long as the registration is the same terminal the cage has not yet been registered as being transported to another terminal.

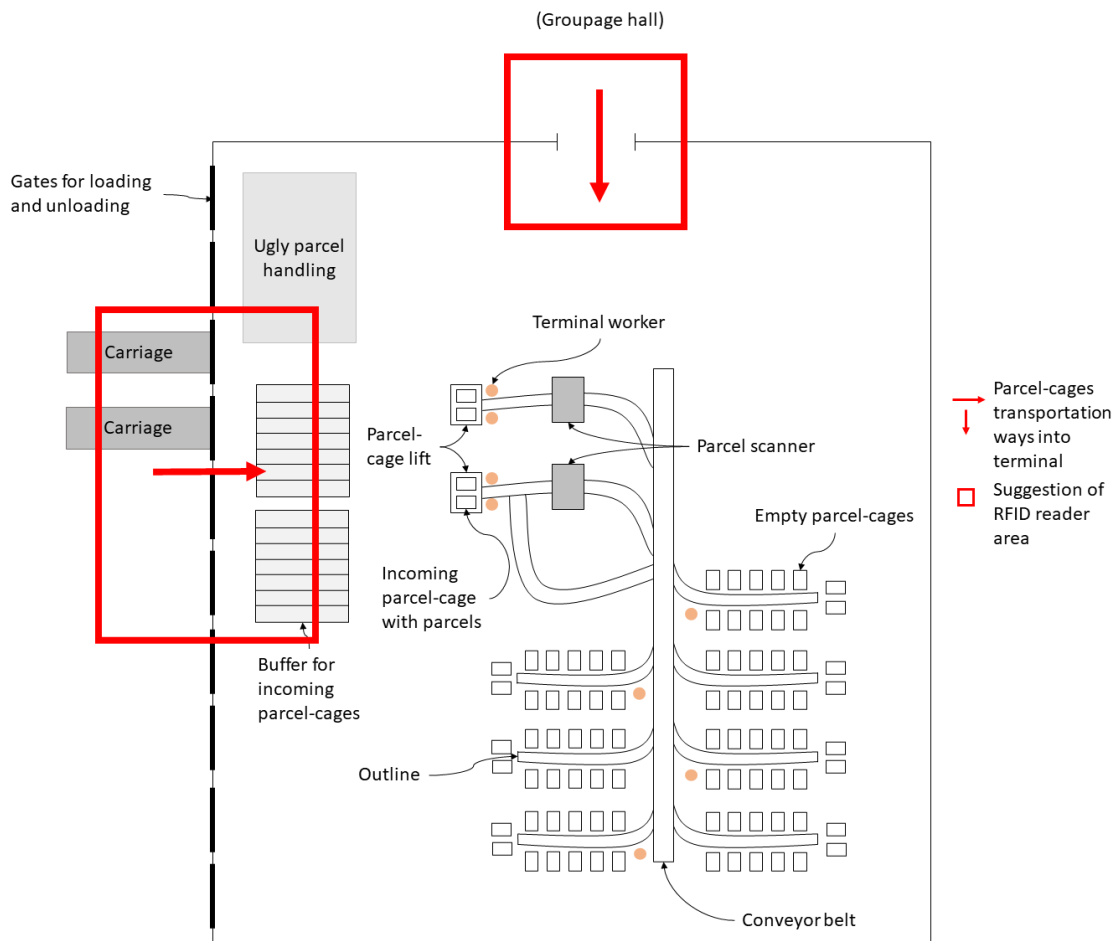


Figure 4.17: Example of how to place the RFID readers in the large-sized terminal.

4.2.2.4 Evaluation of new tracking system

The evaluation of the tracking system will be connected to how the new tracking system can reduce the shortage of cages and which information is needed from the system to address each reason behind the shortage. Table 4.16 presents how the tracking system could reduce the shortage of cages.

Table 4.16: How shortage can be prevented, and required information from new tracking system to address reasons why shortage occurs.

Reasons for shortage of cages	Goals with new tracking system	Information required from system
<i>Variation of production</i>	Facilitate empty cage transportation	Presumed inventory level = Cage balance score + current inventory level
<i>Lack of control of where cages are</i>	Tracking at cage-level	Last registered terminal for cage

The shortage occurring due to variation in production can be reduced by providing information to the workers regarding how the empty cages are transported. The information required would be the cage balance score and the current inventory level which together provides a presumed inventory level of empty cages for each terminal after the daily production.

The low control of where the cages are can lead to a shortage of cages in the production. The shortage can be reduced with tracking on cage-level. Tags, readers and a software system are needed. The information required for better control of the cages is at which terminal the cage had its last registration.

4.3 Comparison between current and new solution

In this section, a comparison will be made between the current and new solutions for the two tracks, parcel-cage size and tracking system.

4.3.1 Parcel-cage size

The current parcel-cage's size is compared to the new cage's size in three factors: transport efficiency and environmental aspect, time of handling cages and physical ergonomics.

4.3.1.1 Transport efficiency and environmental aspect

The transport efficiency considers the average parcels per pallet place the two cages can transport and the load factor for both cages. As presented in Table 4.13, the new parcel-cage can on average transport 68,8 parcels per pallet place compared to 49,6 parcels per pallet place for the current cage. This results in the possibility to transport 39 % more parcels with the same number of carriages.

Since the new cage can transport two cages in one pallet place the new cage utilizes

more of the inside height of the carriage than the current cage. The load factor for the new cage has increased from 62,8 % to 89,9 %, indicating an increase of 43,3 %. The results demonstrate that the transport efficiency is positively affected by the new parcel-cage size.

An example of how the transport efficiency could be changed with the new cage size is presented below. Due to the specific carriages used on the distance between Gothenburg and Jönköping it has the possibility to transport 50 cages per day. This occurs often, especially at the beginning of a week. The average capacity if 50 pallet places are used in the current situation would be around 2480 parcels. The same number of parcels would theoretically fit in 36 pallet places with the new cage, which would free up 14 pallet places. Theoretically, the number of carriages required to transport the same volume of cages could be reduced by 28 %. Figure 4.18 illustrates how many pallet places that are used for the current cage and the change the new cage would make.

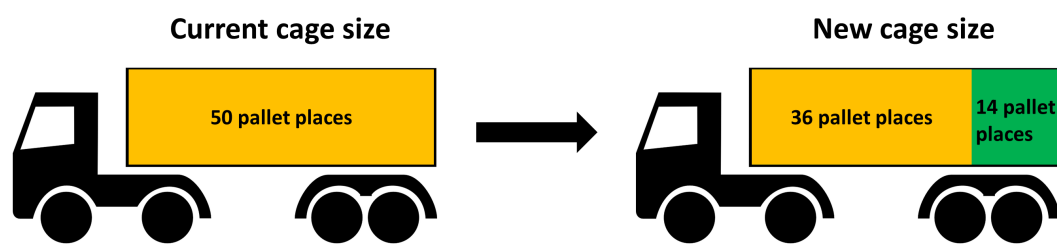


Figure 4.18: Illustration of freed up pallet places for the new cage on the distance between Gothenburg and Jönköping.

4.3.1.2 Time of handling cages

It is difficult to determine exactly how the new cage will affect the time needed for handling the cages. The results indicate several work tasks that will take a longer time to conduct due to more cages needed. The time required for these work tasks will increase by approximately 44 % compared to the current process. The calculation is based on how the process currently works and no adaptations for the new cages are included. There is therefore potential to make changes for a new parcel-cage process that can affect the time factor in different ways.

The identified improvement areas where the extra time can potentially be reduced are to make changes in the work process and to facilitate work with better helping aids. The work process concerns the aspects of when, who and how the work is done. If the worker can perform the work task during a calmer time or when time is not as critical (as it is during production) the time required could potentially be reduced. Who is conducting the work is another important factor to consider. An example is the loading and unloading of cages which can be done by both terminal workers and truck drivers. If the truck driver conducts the work task the terminal worker has

the possibility to conduct other work tasks in the parcel production, which could potentially reduce the extra time needed. How the work tasks are conducted is important to investigate if extra time is put on doing something not value-adding for the production or if the work task could be done differently. To facilitate the work different physical aids or other helping systems could be useful. Physical aids could help by providing the possibility to conduct the task faster. An example is if a forklift would be able to transport more than one cage at a time since the forklifts currently limit the transportation capacity at the terminals. Other systems could facilitate the work, for example the new tracking system that could reduce the shortage of cages, and thus reduce the use of extra cages that takes a longer time to handle.

4.3.1.3 Physical ergonomics factor

The areas identified as the most harmful when it comes to physical ergonomics are packing parcels into the parcel-cage at the outline and the risk of parcels falling out from the cage and harming workers, see section 4.1.3. The shorter height of the new cage leads to lower distances for the parcels to fall and therefore the parcel will achieve a lower drop velocity compared to the current solution.

For the physical ergonomics when packing a parcel into the cage the lifting heights are divided into acceptable and unsuitable lifting height. The proportions of the lifting zones are different for the current and new cage due to the change in height. The same heights for the different zones (Low, Medium and High) are applicable for both cases and Figure 4.19 presents the difference between the zones in the cages. The acceptable and unsuitable proportions for each cage are presented in Figure 4.20. The lower height leads to a change in the unsuitable lifting height resulting in 44 % more acceptable lifting height for the new cage.

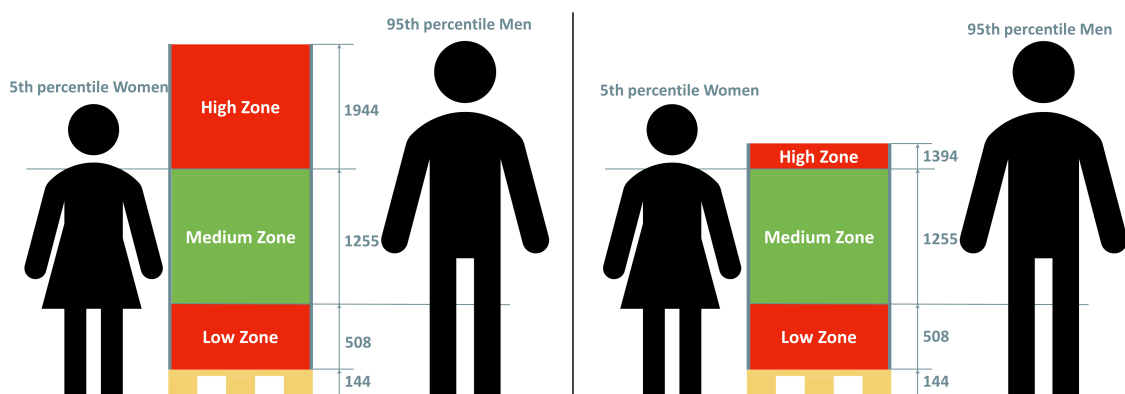


Figure 4.19: Low, Medium and High zones in the current parcel-cage (to the left) and the new parcel-cage (to the right).

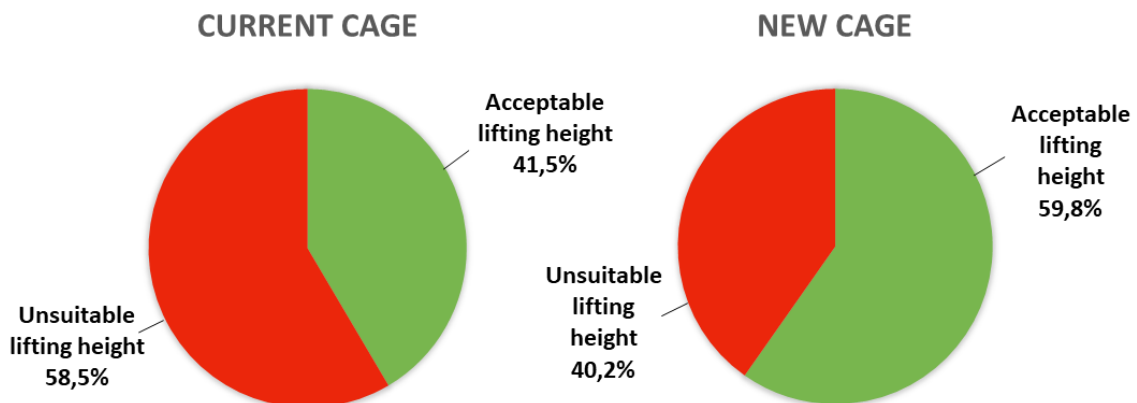


Figure 4.20: Proportions of acceptable and unsuitable lifting zones for current and new cage.

An important factor to mention is the risk of the work being more repetitive due to the larger number of cages needed to transport the same number of parcels. The number of cages needed to be filled and closed can affect the repetitiveness of work for the workers if they have the same work shift length and number of employees working. More rotation between the workstations can lead to less repetitive work.

4.3.2 Tracking system

In this section the current and new tracking systems are compared regarding how they affect the transportation and handling of cages.

4.3.2.1 Transportation

Since the new tracking system is able to track the cages at cage-level this enables better control of the cages. Better control can lead to better information of where the cages are and how they are transported between terminals. This can in turn lead to a better understanding of how empty cages should be transported to reduce shortages. When a shortage of cages is reduced the use of extra cages can also be reduced. Using the standard cages instead of the extra cages is more optimal for the transport efficiency and economical costs.

Thus the new tracking system has the potential to facilitate transportation of empty cages to reduce shortage, gain a better transport efficiency in general and cost less in connection to the use of extra cages.

4.3.2.2 Handling of cages

The current parcel-cage process uses two different systems to register how many cages are transported between the terminals. The proposed new tracking system only uses one manual data collection method together with automatic registrations made when the cage arrives at a new terminal. By reducing the systems used for collecting data the information could become more accurate since the workers only have to know how one system works. Since the data from the database used by the Qlikview application is necessary for the haulage companies to get paid this is no extra task that is added for the workers. As of right now the Cage app process is an "add on" work task. By reducing the work tasks done for registering the cages the parcel-cage production will have one less work task to conduct and time can be saved. This also leads to reduced time in the entire parcel process. When the shortage of cages can be reduced with the new system the extra cages can be used more seldom. The extra cages provide worse physical ergonomics risks for the workers and take more time to pack due to the construction of the cage.

The new tracking system has potential to reduce the time and ergonomic risks when handling the cages.

5

Discussion

This chapter will discuss the result of the study and the different factors deeper, the method used as well as which future research could be done to move further on with the project. The results suggest that the transport efficiency and physical ergonomics in the parcel process will change for the better with the new solution. The time factor regarding the handling of cages due to the change in cage size is implied to become longer, thus have a negative effect, due to more cages utilized. On the other hand, the tracking system implies a shorter time needed in the parcel process since a work task in the daily production can be reduced.

Both the terminal workers and truck drivers are affected by the new solution. The terminal workers are affected by the potentially better ergonomics and increased handling time of the cages at the terminals. The loading and unloading of cages can be done either by a truck driver or a terminal worker. Both of them are affected by the longer handling time it will take to load and unload cages into the carriage. The new solution needs 44 % more new cages to transport the same volume of parcels, thus for this work task the time needed will increase. It is however important to take into consideration that the transport efficiency has potential to increase by 39 % with the new cages. This indicates that fewer carriages are needed to transport the same volume of parcels between terminals, which in turn leads to a decrease in time for the truck drivers. The handling time of the cages at the terminals will increase due to the larger number of cages. However, the more efficient transportation of the cages can decrease the overall time change since fewer carriages are needed to transport the same volume of parcels. This needs to be investigated closer.

Interrelations between different factors investigated can make it difficult to say just how much change an specific factor might have. It is the combination of all factors that will lead to a combined effect on the parcel production. Factors investigated in this project were handling time, physical ergonomics and transport efficiency. A wide range of factors investigated is important to gain a broad understanding of the effects.

On the market today there are two types of cages available similar to the current cage. The difference between the cages is where the gate is located, on the long side or short side of the cage. There are pros and cons to both types of cages. The current production is adjusted for cages having the gate on the short side and therefore this project investigated these types of cages.

The new parcel-cage uses bars to fit two cages on top of each other inside the carriage. There are alternatives with cages being stacked on top of each other with the help of plates that are put on one cage enabling another one to be stacked on top of it. The stacking alternative should be further investigated to see what pros and cons it has compared to the proposed new cage with the use of bars.

5.1 Handling of cages

Two factors were investigated regarding the handling of the cages: the time factor and the physical ergonomics factor. As the results imply, it is reasonable that changing the size of the cage would increase the handling time for some work tasks so that more cages are needed to transport the same volume of parcels. However, the new tracking system suggests a reduction of work tasks connected to registering the cages, from two tasks to one. This affects the entire parcel process and reduces the time for handling the cages. The work task suggested to be reduced occurs during different time periods for the departing terminal. Depending on which time period (before, during or after production), it affects the parcel-cage process differently. How large an impact the new solution has for the cage-handling time needs to be investigated more closely.

It is likely that the physical ergonomics would become better for the new solution since the proportions of acceptable lifting height and the unsuitable would be favorable due to the lower height. The lifting in the lower and medium lifting height will become more frequent, but overall the lifting of parcels into the new cage will have a larger number of lifts within the acceptable lifting zone compared to the current cage.

5.1.1 Time

The result of the time required for the new cage size compared to the current one only regards the current parcel-cage process and the handling time at the terminals. In the comparison (section 4.3) a list of aspects that affect the time factor is compiled. It is important to understand how potential changes can be made to a new parcel-cage process to further influence the time factor. Something important to emphasize is that the tracking system has potential to reduce the time needed in the process.

The handling time takes the work tasks at the terminals into consideration. However, it is also important to emphasize that the transportation time has potential to be reduced for the new solution since fewer carriages are needed due to a carriage's potential to transport 39 % more parcels. The overall time change, that is the time of handling cages at the terminal and the transportation time, needs to be investigated further since this is a key aspect to whether the new solution can be effective in the long run.

5.1.2 Physical ergonomics

Different people have different characteristics when it comes to biological variation, like age or gender. It is important to consider these variations when discussing physical ergonomics regarding the parcel-cages. One aspect that is of high importance to consider is the height of the workers. When evaluating the physical ergonomics the design principle to rule out the extremes (taking 90 % of the Swedish working population into account) was used to divide the cage into different lifting zones (Low, Medium and High), see Figure 4.6. However, the Low, Medium and High lifting heights can also be seen to be specific for each worker depending on their knee-level and shoulder heights. For example, taller workers will tend to have a shorter unsuitable interval in the "High zone" and larger interval in the "Low zone", and vice versa for the shorter workers. The workers' behaviour when putting the parcels into the unsuitable lifting heights plays an important role. When putting the parcel in the "Low zone" workers can bend their knees instead of backs to cause less physical loading of the body. However, for the "High zone" there is no simple way of improving the physical ergonomics using the worker's own body. Perhaps an alternative helping aid, like a footstool would enable better physical ergonomics in this lifting height. This indicates that the shorter workers might potentially have more physical loading of their body than the taller ones when packing a cage due to the "High zone". The new cage size reduces the "High zone" significantly and results in around 50 % of men and women having their shoulder height above the cage's highest point (about 1,4 m), thus the physical ergonomics problem will be reduced.

The cube model evaluation takes the time and repetitiveness of the entire work tasks of packing parcels in the cage into account. The situations evaluated are part of the work task, but they might occur with differing frequency depending on which situation it is and which worker does the work task. The worker might have had different training in how to pack a cage during different harmful situations or packing strategies. The workers might adapt the training they have received differently into the real situation.

5.2 Transportation of cages

The calculations made regarding the transport efficiency and load factor for the current and new cage size suggest both of the factors to become better for the new cage. Since the load factor is higher for the new cage, due to two cages fitting in one pallet place, it is reasonable that the average number of parcels per pallet place would be higher for this solution as well.

5.2.1 Transport efficiency

A current behaviour that occurs when the workers are packing the cages is that the parcels often "stick out" from the top of the cage. The current cage is not sensitive to this behaviour since there is a gap in height between the top of the cage and the ceiling. However, the new cage will be more sensitive to this behaviour since it can not be fitted into the carriage otherwise. This is something that is important to have in mind when redesigning the size of the cage.

The length of parcels transported on the conveyor belt is normally restricted to be 1,4 m due to the turning radius on the belt. A limitation in the project was to only investigate a cage for parcels possible to transport on the conveyor belt. However, the new cage's inner height is 1,25 m resulting in a number of parcels transportable at the conveyor belt not being able to fit into the new cage.

Different transportation distances transport different numbers of parcel-cages each day. There is everything from a full carriage of cages to one or a couple of cages mixed with groupage products. Both of the cases will benefit from the new cages if the carriage uses bars to stack the cages or other groupage on to utilize the entire volume of the carriage. However, it is not that common in some haulage companies to have and use the bars today which can lead to decreased utilization of the carriage if the companies continue to work without bars.

5.3 Tracking system

The proposed new tracking system would provide a possible solution for the problems with shortage of cages both in a long- and short-term. This due to the tracking at cage-level and due to the system being able to provide information regarding how the cages are transported between terminals to facilitate empty cage transportation.

For the tracking system to work efficiently it is important for the reader at the terminals to be put on locations where the cages are transported when they are arriving at the terminal. However, keeping the number of readers needed down is important from an economical point of view since this is the expensive part of the system.

Another type of issue that comes along with the new tracking system is when the cages are disassembled to enable more efficient empty cage transportation. When they are assembled again it is important that the cages receive one tag on each cage, not more or less.

RFID tags are normally sensitive metal since it disturbs the connection between the reader and the tag. However special tags exist that are developed to work on metal objects and should be used in this case. It is important to further investigate what types of tags exist on the market.

5.4 Sustainability and ethics

This project's sustainable effects on the environment, economy and socially are discussed below. With a higher load factor and transport efficiency more parcels will be able to fit into the carriage reducing the number of trucks needed by theoretically 28 % for transportation of the same volume of parcels. Fewer trucks needed leads to the opportunity to reduce emissions and therefore possibly also a reduced environmental impact. The reduced number of trucks for transporting the same volume of parcels also leads to a more economical sustainability. The new tracking system is suggested to gain better control of the cages and reduce the shortage of them. This could lead to fewer cages disappearing and therefore the possibility to use the cages more efficiently and for a longer time. It can also lead to decreased use of extra cages that are only used once, which affects the economical and environmental aspects. The project also concerns the social sustainability for the workers regarding the physical loading of their bodies. The physical loading is suggested to decrease for the workers when using the new cage due to a lower height of the cage.

Regarding the ethics in the project the protection of the participants' privacy has been of large importance. The participants in interviews and observations in this project are deliberately not mentioned by name. The workers' behaviour while working was studied to gain information of for example their physical ergonomics when packing parcels into a cage. This was done with the purpose to improve their working conditions. The data in the study needs to be handled carefully but for the purpose of the project it can be justified. The project considers the terminal workers and truck drivers when it comes to the parcel-cage process. Moving further with the project, consequences for other workers and stakeholders need to be considered as well.

5.5 Method

A triangulation of methods was used in this project, which made it possible for cross verification of data from several sources. This method reduces the risk of subjectivity in the studies conducted which could make the result less influenced by whom is conducting it.

The cube model used for the physical ergonomic evaluation is more of a guiding tool than an actual method for evaluating ergonomics. Therefore, the aspects in the cube model were evaluated deeper with models from the SWEA's provision. Since the project was interested in looking at the ergonomics in a more overall way this method was chosen. Other methods go deeper into exact working postures etc., which might be helpful in a later stage of the project.

The data from the Qlikview application was thoroughly investigated to understand if it was reliable and probable. Some data was identified as not reliable, thus taken away from the calculations. Specific data were compared to the result in the qualitative study to gain a broader understanding of whether it would be probable or not. However, more in-depth investigations could have been done to compare the data the terminal workers write in the system with what actually is transported. Due to time restrictions this was not possible.

Some calculations for the new parcel-cage were done by calculating a difference between the inside volume of the current and new cages. The volume change was then used to compare the new solution with the current one regarding transport efficiency and the proportion of more cages needed. This is a broad approximation of the actual difference since it does not take other factors into consideration, like how to transport parcels longer than the inside height of the new cage. However, at this stage in the project and due to time restrictions the approximation provided a good overview of the potential impacts.

The method used for mapping and analyzing the current parcel-cage process was process flow charts. The two terminals investigated conducted work tasks at different times in the process and on different occasions. The generalized flow chart is therefore not an example of how it works in detail at either of the terminals, but it provides an overview of how the process mostly is conducted in order to compare and evaluate the new solution further. Differences might occur depending on who is doing the job and when it is done (for example during different periods over the year with low, medium or high period of parcels sent in production). Since the two terminals differ from each other on some points it is crucial to investigate more terminals to understand if the result can be seen as general for more than the two terminals investigated. Thus, a more in-depth study should be done if the map is going to be applicable for several terminals. In the two terminals specific flow charts with more details can be found on how the process actually works at the terminals. This can be useful in improvement work of the process to find and reduce waste. However, it was not within the scope of the project, thus the generalized flow chart is an easier way to present the parcel-cage process and to work further with it.

Supplementary studies to collect information and data firsthand would have been useful but were not possible due to time restrictions. For example, a study collecting data on how many parcels that are transported on average per cage could have provided a better understanding of what was included and excluded in the data.

5.6 Covid-19

The Covid-19 pandemic was present throughout the project. At the beginning of the project, some restrictions were applied from the company regarding traveling to the terminals. The project got approval to visit two out of 28 terminals in which the studies were made. After the terminal visits, new restrictions came which made it

impossible to visit the two terminals more times. Some supplementary studies were therefore not possible to conduct and all extra information needed for the project needed to go through the terminal team leaders. Since there is some difference in how the workers in different terminals conduct their work it would have given a more comprehensive result to visit more terminals to gather more data and information.

5.7 Future work

Several areas are of interest to investigate further regarding this project.

- How the parcels are utilizing the space inside the new cage compared to the current cage.
- How transportation should be done of parcels longer than 1,25 m (inside height of new cage).
- How to prevent parcels falling from the cage.
- How the different packing strategies affect the physical loading of the body, and how the different loading factors (force, posture, time) affect the strategies.
- How other factors not investigated in this project are affected by a new cage, like economic effects of the new cage size and tracking system.
- How different aspects within production can be changed to reduce the extra time needed for handling the new cages.
- Which products will be used for the new solution (such as the the new cages and tracking devices) taking into consideration: competitor analysis and sustainability of products.
- How the transportation time will differ for the new solution due to the change in transport efficiency and how it affects the overall time needed in the parcel-cage process.

6

Conclusion

This section will present a conclusion of the findings for the two research questions in the study.

6.1 Research Question 1

”How will a new parcel-cage size, optimizing the linehaul transportation, affect transport efficiency, ergonomics and time required for handling cages?”

The new cage size is defined to have a total height of 1,4 m (current cage: around 2 m) which allows two cages to be stacked on top of each other in the carriage. The study suggests that the transport efficiency and physical ergonomics will become better with the new parcel-cage size, while the time it takes for handling the cages will increase.

Transport efficiency

The transport efficiency will increase by 39 % from the current to the new cages due to more parcels on average fitting into a pallet place. The size of the cages will also lead to an increase in the load factor of the carriage with 43,4 %. The results suggest that the transport efficiency is positively affected by the new parcel-cage size.

Physical ergonomics

The riskiest work task from a physical ergonomics perspective was identified to be the packing of parcels into cages. The study divided the cage into three zones where the medium zone (from knee-level to shoulder height) is within acceptable lifting height for 90 % of the working population and the low and high zones are of an unsuitable lifting height. The study indicates that the height difference between the current and new cage results in a 44 % better acceptable lifting height for the new cage.

An evaluation of the physical loading for combined situations with different weights of parcels, posture and time was done. The combination of high weight of parcels (>15 kg) and unsuitable lifting height resulted in the riskiest situations with regard to the physical loading of the body. This was followed by medium weight of parcels (3-15 kg) in the unsuitable lifting heights and high-weight parcels in the acceptable lifting height.

Time required for handling cages

The study has also shown that the number of new cages needed to transport the same volume of parcels as the current cages will increase by 44 %. Some work tasks will therefore have an increased time of handling the cages as a result. Some identified improvement areas have potential to decrease the extra time needed for handling the new cages. These are to make changes in the work process and to facilitate work with better helping aids.

6.2 Research Question 2

”What kind of tracking system could be implemented and used in the future to improve the accessibility and control and reduce shortage of parcel-cages in the process?”

The study suggests that shortage in short- and long-term can be reduced with better control of the cages using cage-level tracking. This can be done with the help of a passive UHF RFID system where the cages could become more accessible due to better control of the cages' whereabouts. The findings indicate that short-term shortage occurring due to variation in production can be reduced by providing information to the workers regarding how the cages are transported and the inventory level of empty cages at each terminal to facilitate empty cage transportation.

Better control of cages will be possible due to the RFID tags fixed on each cage and the readers fixed in the terminals. The automatic registration provides knowledge of where the cages are located. To ensure no disappearing of cages from the process a manual inventory can be done to see if it differs compared to the automatic registration. The data gathered when the transportation document is written in the computer (the Qlikview application database) should be used to collect information on how the cages are transported between the terminals. This information will result in a daily cage balance score where the change in the number of cages at a specific terminal is calculated as the number of cages sent away minus the number of cages received. The presumed inventory level of empty cages after the daily production is calculated as the current inventory plus the daily cage balance score. This information will provide knowledge for how empty cages should be transported.

The implementation of the system requires tags, readers and a software system. For the tags the long side of the cage is suggested for the attachment since it is needed for a cage to be transported and it is more seldom taken away, except for when it is disassembled. The fixed readers will be put on locations where the cages always pass when they arrive at the terminal, allowing the registration of the cage to be done directly at arrival. All possible alternatives should be covered, but common areas within the facility should be found to reduce the number of readers needed. Implementation for the connection between the data in the Qlikview application and the data gathered from the tags and readers in the tracking system should be done.

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A

Interview questions

The following pages present the interview templates in the language they were conducted in.

A.1 Interview questions - Terminal worker

Terminalarbetare - intervjumall

Allmänt:

- Vad heter du?
- Hur gammal är du?
- Vilken terminal jobbar du på?
- Vad är din nuvarande arbetsroll?
 - Hur länge har du haft den rollen?
- Har du haft någon annan roll här på Schenker?
- Hur länge har du jobbat på Schenker totalt?

Arbetsuppgifter och pakethantering.

- Vad är dina huvudsakliga arbetsuppgifter under en vanlig dag?
 - Vilka av dessa arbetsuppgifter är på något vis kopplade till paketburarna?
Motivera gärna ditt svar.

Gå igenom arbetsuppgifterna kopplade till pakethanteringen: **TERMINAL 1**

- Hur gör du när du **förbereder paketbanan**?
 - *Ställ upp burar vid outlines:*
 - Hur vet du vart burarna ska placeras?
 - *Sätt på burflagg och användning av burappen:*
 - Hur vet du vilken burflagg som ska till vilken bur?
 - Hur använder du dig av burappen?
 - Finns det några svårigheter med denna aktiviteten (burflagg och burappen)?
- Om vi nu tänker oss att du **arbetar på paketbanan** vilka moment görs då?
 - Är det någon arbetsuppgift som är svårare eller tyngre fysiskt än de andra?
 - Isåfall vilken och varför?
- Arbetsuppgifter:
 - *Framkörning av burar till lyften*
 - Kan du komma på några problem som kan uppkomma i detta steget?
 - *Påkastet*
 - Ser du några problem med burarnas utformning som hindrar ditt arbete vid påkastet?
 - *Packa paket i paketburar*
 - Hur gör du när du packar paketen i paketburarna? Har du någon speciell strategi för det?
 - Ex. Tunga paket? Stora paket? Små paket?
 - *Byte av paketbur om en blir full under passet*
 - Hur går det till?
 - Finns det några svårigheter med burbytet?
 - Hur används burflagg och burappen om en ny bur sätts in?
 - Ungefär hur ofta byter ni ut fulla burar mot tomma burar under passet?
- När alla **paket är sorterade**: Vilka arbetsuppgifter görs då?
 - *När ni ska transportera de färdigsorterade paketburarna från outlines vid banan till de specifika linjerna för vidare transport:*

- Hur går det till?
 - Vad behöver du veta för att buren ska komma rätt?
 - Hur går du tillväga om du inte vet vart den ska?
- När lämnar ni över ansvaret för buren och till vem?

Gå igenom arbetsuppgifterna kopplade till pakethantering: **TERMINAL 2**

- **Transport av paketbur till paketbanan**
- När tar ni över ansvaret för burarna när de kommer till terminalen?
 - Vem är ansvarig att transportera burarna till paketbanan?
- Om vi nu tänker oss att du **arbetar på paketbanan** vilka arbetsuppgifter gör du då?
 - Är det någon arbetsuppgift som är svårare eller tyngre fysiskt än de andra?
 - Isåfall vilken och varför?
- **Arbetsuppgifter:**
 - *När burarna är vid paketbanan tills det att de är i burliften: (Framkörning av burar till liften)*
 - Finns det något problem som kan uppkomma i detta steget?
 - *Påkastet*
 - Ser du några problem med hur burarna ser ut idag som hindrar ditt arbete vid påkastet?
 - *Packa paket i paketburar*
 - Hur gör du när du packar paketen i paketburarna? Har du någon speciell strategi för det?
 - Ex. Tunga paket? Stora paket? Små paket?

Övrigt angående paketburarna:

- Är det något speciellt du tänker på att man behöver veta när man hanterar burarna?
 - Ex. Hur vet du vart burarna ska placeras för vidare transport?
 - Ex. Hur packas paketen i burarna?
- Ser du något problem med hur paketburarna hanteras eller transporteras idag på terminalen?
 - Hur hade du velat göra det istället?

Ergonomi:

- Har du råkat ut för någon fysisk skada eller överbelastning i samband med pakethantering?
 - Om ja: Vad för skada/överbelastning?
 - Om ja: Hur uppkom skadan/överbelastningen?
 - Vilket arbete skulle utföras?
- Är det någon arbetsuppgift eller station som du anser är mer riskfylld än det kommer till pakethantering?
 - Vilken/vilka arbetsuppgifter?
 - Vilka risker ser du med det?
- När det kommer till paketburarna: ser du några risker för fysiska skador eller överbelastning vid hantering och transport av dem?

Tracking-systemet: (Spårningssystemet)

- Hur tycker du att det fungerar med Burflaggen?

- Vad tycker du är bra?
- Vad tycker du är mindre bra?
- Använder ni er av Burappen under ankommande skift?
- Är det någon information angående burarna som hjälper dig i ditt arbete?
 - Saknar du någon information om burarna?
 - Vilken?
- *En fullständig bur består av en EURO-pall, 2 långsidor och 2 grindar. När det kommer till fjärrtransporten:*
 - Skickas burarna alltid fullständiga?
 - Kan du komma på något tillfälle då de inte gör det?
 - Om ni har brist på någon av delarna till en bur - hur löser ni transporten av den då?

Brist på burar:

- Hur ofta händer det att ni inte har tillräckligt med burar?
- Vad gör ni om ni inte har tillräckligt med burar när ni behöver dem?
 - Vilka lösningar finns det?
 - För- och nackdelar med alternativa lösningar?

Övrigt:

- En förändring på storleken av paketburarna påverkar hela processen. Vilka konsekvenser tror du det medför?
 - Konkret exempel.
 - Ex. hur påverkar det hanteringen av burarna?
 - Hur påverkar det den fysiska ergonomin?
- Är det något annat du vill kommentera angående pakethanteringen eller generellt?
- Har du några frågor till mig om mitt examensarbete?

A.2 Interview questions - Team leader

Arbetsledare - intervjumall

Allmänt:

- Vad heter du?
- Hur gammal är du?
- Vilken terminal jobbar du på?
- Vad är din nuvarande arbetsroll?
 - Hur länge har du haft den rollen?
- Har du haft någon annan roll här på Schenker?
- Hur länge har du jobbat på Schenker totalt?

Allmänt om terminalen:

- Hur många terminalarbetare arbetar med pakethantering för avående/ankommande paket varje skift?
- Ungefär hur många paket hanterar ni varje dag för avgående respektive ankommande?

Arbetsuppgifter och pakethantering.

- Vad är dina huvudsakliga arbetsuppgifter under en vanlig dag?
 - Vilka arbetsuppgifter utför terminalarbetarna normalt under en vanlig dag?
 - Vilka av dessa **arbetsuppgifter** är på något vis kopplade till paketburarna? Motivera gärna ditt svar.
- Vad skulle du säga att syftet med paketburarna i fjärrtransporten är?
 - Används burarna som det är tänkt att de ska göra?
 - I vilka fall gör de inte det?
 - Vad beror det på?

Aktiviteter/arbetsuppgifter

- **TERMINAL 1**
 - När skulle du säga att processen för fjärrburarna påbörjas?
 - När lämnar ni på terminalen över ansvaret för burarna och till vem?
 - Hur vet nästa person att ni lämnat ansvaret till dem?
- **TERMINAL 2**
 - När får ni på terminalen över ansvaret för burarna och från vem?
 - Hur vet ni att ansvaret är överlämnat till er?
 - När skulle du säga att processen med fjärrburarna slutar?
 - När behöver ni inte burarna mer?
- Vilka moment ingår i processen med fjärrburarna, dvs det flöde du beskrev start och slut på.
 - Är det några av dessa moment du tror kommer påverkas av att ändra storleken på paketburarna?
- Ser du något problem med nuvarande paketburar när det kommer till hanteringen av dem för terminalarbetare eller chaufförer?
- Händer det att burar kommer till fel terminaler?
 - Vad tror du det beror på?

Transport:

- Ser du något problem med nuvarande paketburar när det kommer till transporter av dem (både på terminalen och mellan terminaler)?

Ergonomi:

- Har **du eller** någon medarbetare råkat ut för någon fysisk skada eller överbelastning i samband med pakethantering?
 - Om ja: Vad för skada/överbelastning?
 - Om ja: Hur uppkom skadan/överbelastningen?
 - Vilket arbete skulle utföras?
- Är det någon arbetsuppgift eller station som du ser som extra riskfylld med när det kommer till fysiska skador eller överbelastning kopplat till pakethantering?
 - Vilken/vilka arbetsuppgifter?
 - Vilka risker ser du med det?
- När det kommer till paketburarna: ser du några risker för skador för terminalarbetare eller chaufförer vid hantering och transport av dem?

Tracking-systemet: (Spårningssystemet)

- Hur tycker du att nuvarande spårningssystem med Burflagg och Burappen fungerar?
 - Vad tycker du är bra med systemet?
 - Vad tycker du är mindre bra?
- Använder du som arbetsledare burappen idag?
 - Hur? Till vadå?
 - Vilken information hjälper dig i ditt arbete?
 - Vilken information hade du önskat tagit del av från ett spårningssystem för paketburar?
 - Varför använder du inte appen? (bara om detta inte görs)
- Vilken information skulle du säga är krav på att finnas i ett spårningssystem?
 - Vilken information hade du velat sätta som önskemål att ha med i systemet?
- *En fullständig bur består av en EURO-pall, 2 långsidor och 2 grindar. När det kommer till fjärrtransporten:*
 - Skickas burarna alltid fullständiga?
 - Kan du komma på något tillfälle då de inte gör det?
 - Om ni har brist på någon av delarna till en bur - hur löser ni transporten av den då?

Brist på burar:

- Hur ofta händer det att ni inte har tillräckligt med burar?
- Vad gör ni om ni inte har tillräckligt med burar när ni behöver dem?
 - Vilka lösningar finns det?
 - För- och nackdelar med alternativa lösningar?
- Baserat på dina egna erfarenheter, vid vilka tillfällen tror du paketburarna försvinner ur systemet?
- Vad tror du burbristen beror på?
- Hur tror du att burbristen kan undvikas?

Övrigt:

- En förändring på storleken av burarna, till en lägre höjd, påverkar hela processen. Vilka konsekvenser tror du det medför?
 - Konkret exempel.
 - Hur tror du arbetsuppgifterna kommer påverkas?
 - Hur påverkar det hanteringen av burarna?
 - Hur påverkar det den fysiska ergonomin?
- Är det något annat du vill kommentera angående pakethanteringen eller generellt?
- Har du några frågor till mig om mitt examensarbete?

A.3 Interview questions - Terminal manager

Terminalchef - intervjumall

Allmänt:

- Vad heter du?
- Hur gammal är du?
- Vilken terminal jobbar du på?
- Vad är din nuvarande arbetsroll?
 - Hur länge har du haft den rollen?
- Har du haft någon annan roll här på Schenker?
- Hur länge har du jobbat på Schenker totalt?

Allmänt om terminalen:

- Hur många terminalarbetare arbetar med pakethantering för avående/ankommande paket varje skift?
- Ungefär hur många paket hanterar ni varje dag för avgående respektive ankommande?

Arbetsuppgifter och pakethantering.

- Vad är dina huvudsakliga arbetsuppgifter under en vanlig dag?
- Vilka arbetsuppgifter utför terminalarbetarna normalt under en vanlig dag?
 - Vilka av dessa arbetsuppgifter är på något vis kopplade till paketburarna? Motivera gärna ditt svar.
- Vad skulle du säga att syftet med paketburarna i fjärrtransporten är?
 - Används burarna som det är tänkt att de ska göra/finns det undantag?
 - I vilka fall gör de inte det?
 - Vad beror det på?

Aktiviteter/arbetsuppgifter i produktionen:

- T1:
 - När skulle du säga att processen för fjärrburarna påbörjas?
 - När lämnar T1 över ansvaret för burarna och till vem?
 - Hur vet nästa person att ansvaret är överlämnat till dem?
- T2:
 - När tar T2 över ansvaret för burarna och från vem?
 - Hur vet ni att ansvaret är överlämnat till er?
 - När skulle du säga att processen med fjärrburarna slutar?
 - När behöver ni inte burarna mer?

Transport och hantering:

- Ser du något problem med nuvarande paketburar när det kommer till transporter av dem (både på terminalen och mellan terminaler)?
- Vad fungerar bra med när det kommer till transporter (både på och mellan terminaler) av burarna på terminalen idag?

- Vad fungerar mindre bra?
- Ser du något problem med nuvarande paketburar när det kommer till hanteringen av dem för terminalarbetare och chaufförer?
- Vad fungerar bra när det kommer till hanteringen av burarna på terminalen idag?
 - Vad fungerar mindre bra?

Ergonomi:

- Vad skulle du säga är vanliga skador och överbelastningar som terminalarbetarna råkar ut för i deras arbete?
- Hur ofta händer skador?
- Har någon medarbetare råkat ut för någon fysisk skada eller överbelastning i samband med pakethanteringen?
 - Om ja: Vad för skada/överbelastning?
 - Om ja: Hur uppkom skadan/överbelastningen?
 - Vilket arbete skulle utföras?
- Är det någon arbetsuppgift eller station som du ser som extra riskfylld med när det kommer till fysiska skador eller överbelastning kopplat till pakethanteringen?
 - Vilken/vilka arbetsuppgifter?
 - Vilka risker ser du med det?
- När det kommer till paketburarna: ser du några risker för skador för terminalarbetare eller chaufförer vid hantering och transport av dem?

Tracking-systemet:

- Hur tycker du det fungerar med Burflaggen idag?
 - Vad är bra?
 - Vad är mindre bra?
- Hur tycker du det fungerar med Burappen?
 - Använder du dig något av den idag?
 - Vilken information hjälper dig i ditt arbete?
- Vilken information hade du önskat tagit del av från ett spårningssystem för paketburar?
- Vilken information tror du hade underlättat arbetet för terminalarbetarna/arbetsledarna när det kommer till ett spårningssystem av paketburarna?
- Vilken information skulle du säga är ett krav på att finnas i ett spårningssystem?
 - Vilken information hade du velat sätta som önskemål att ha med i systemet?

Brist på burar:

- Hur ofta händer det att ni inte har tillräckligt med burar?
- Vad gör ni om ni inte har tillräckligt med burar när ni behöver dem?
 - Vilka lösningar finns det?
 - För- och nackdelar med alternativa lösningar?
- Baserat på dina egna erfarenheter, vid vilka tillfällen tror du paketburarna försvinner ur systemet?
- Vad tror du burbristen beror på?
- Hur tror du att burbristen kan undvikas?

Övrigt:

- En förändring på storleken av burarna, till en lägre höjd, påverkar hela processen. Vilka konsekvenser tror du det medför?
 - Konkret exempel.
 - Hur tror du arbetsuppgifterna kommer påverkas?
 - Hur påverkar det hanteringen av burarna?
 - Hur påverkar det den fysiska ergonomin?
- Är det något annat du vill kommentera angående pakethanteringen eller generellt?
- Har du några frågor till mig om mitt examensarbete?

A.4 Interview questions - Truck driver

Chaufförer - intervjumall

Allmänt:

- Vad heter du?
- Vilket åkeri jobbar du på?
- Hur gammal är du och hur länge har du kört för Schenker?
- Vilken/vilka sträcka kör du med lastbilen?
 - Hur ofta kör du denna?

Annat allmänt:

- Vad är maxhöjden på lastbilen?
 - Är det samma för alla lastbilar som körs på fjärrlinjen på ditt åkeri?
- Vad är höjden upp till bommarna som man kan fälla ned?

Arbetsuppgifter och pakethantering.

- Vad är dina huvudsakliga arbetsuppgifter under en vanlig dag?
 - Vilka av dessa **arbetsuppgifter** är på något vis kopplade till paketburarna?
Motivera gärna ditt svar.

Aktiviteter: Tar över/lämnar ansvar för burarna:

- När tar du över ansvaret för paketburarna?
 - Vad är startskottet för att lasta in burarna i lastbilen?
- Vad är det sista du gör för att lämna över ansvaret för burarna till terminal 2?
- Vilka moment/arbetsuppgifter utför du från det att du tar över ansvaret för burarna på T1 till att du lämnar över ansvaret på T2?
 - Vem är ansvarig för att lasta in/ut burarna i lastbilen?
 - Hur vet du att en specifik bur ska med din lastbil?

Övrigt angående paketburarna:

- Har ni tillgång till truckar på terminalerna? (observation?)
- Ser du några problem med hur paketburarna hanteras vid transport idag?
 - Hur hade du velat göra istället?
- Händer det någon gång att du måste prioritera vilka burar du kan få med i lastbilen?
 - Hur prioriterar du då?

Ergonomi:

- Har du råkat ut för någon fysisk skada eller överbelastning i samband med paketburshantering?
 - Om ja: Vad för skada/överbelastning?
 - Om ja: Hur uppkom skadan/överbelastningen?
 - Vilket arbete skulle utföras?
- Ser du några risker för fysiska skador eller överbelastning kopplade till hantering och transport av paketburarna?

Tracking-systemet:

- Hur använder du dig av Burflaggen idag?
 - Hur tycker du att det fungerar?

- *En fullständig bur består av en EURO-pall, 2 långsidor och 2 grindar. När det kommer till fjärtransporten:*
 - Skickas burarna alltid fullständiga?
 - Hur kan det se ut annars?

Övrigt:

- Är det något annat du vill kommentera angående paketburarna?
- Har du några frågor till mig angående mitt examensarbete eller liknande?

B

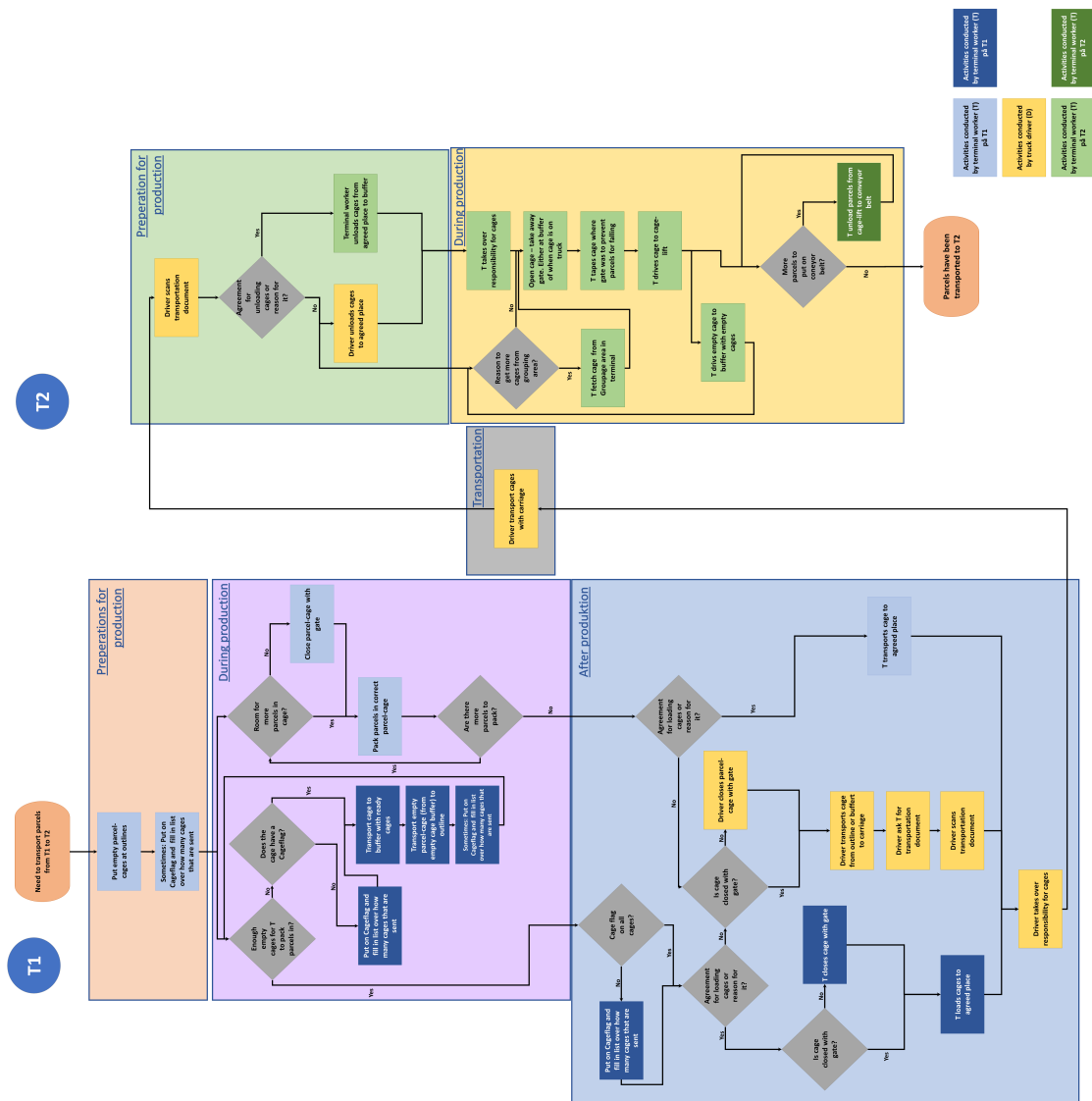
Data not considered from Qlikview application

- Common for parcel and parcel-cages
 - Two terminals register incorrect information when it comes to the number of parcel-cage that are sent from their terminals, which was the reason why both terminal's statistics of parcels and parcel-cages sent are not considered.
 - Other small relations, such as direct parcels from customer to arriving terminal, are unclear whether they are reported in the Qlikview application, but are of small quantity compared to other flows, thus is anticipated to not make much difference in this case.
- Parcels
 - Parcels where departing and arriving terminal is the same are not included in the statistical data since the cages used for sorting these parcels are not included in the Qlikview application (since no haulage company should get paid for the transportation of them).
- Parcel-cages
 - The contract regarding empty parcel-cages transported in between terminals is excluded since they are not transporting any parcels.
 - Parcel-cages are sent to the hub in Jönköping when they cannot be sent directly to the end terminal for some reason. These parcel-cages are sorted into trucks in Jönköping and distributed all over the country. The parcel-cages are scanned the first time when they are going with the truck to Jönköping, using the contract "Fixed booking", and another time when they leave Jönköping for their final destination, using the contract "from JKP hub". The parcel-cage is therefore scanned two times but is still transporting the same number of parcels, thus the contract "from JKP hub" is not taken into consideration for the calculations.

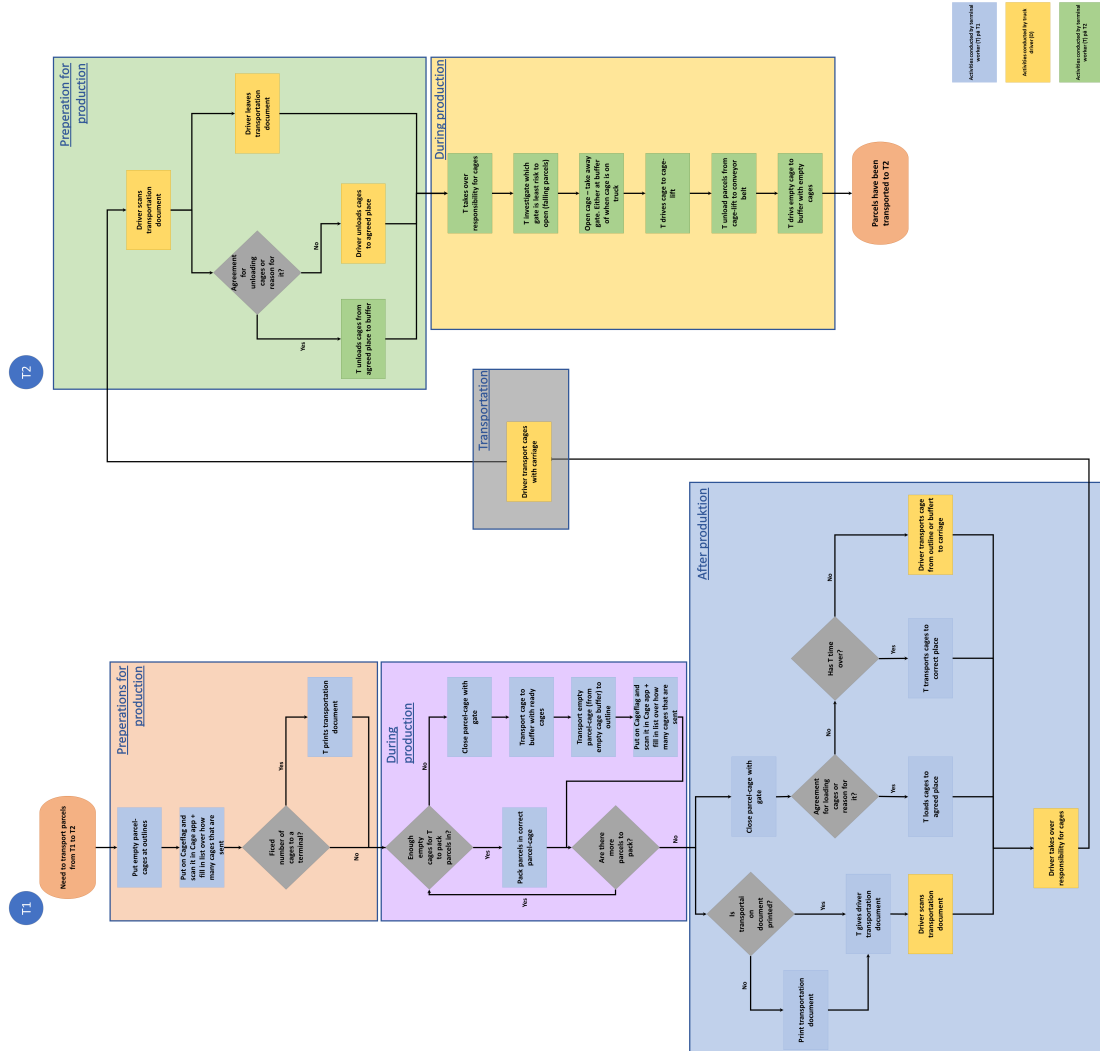
C

Process mapping flowcharts

C.1 The large-sized terminal



C.2 The medium-sized terminal



D

Harmful packing behaviour

Packbehaviour	Explanation	Why	Reason behind	Risks	Improvement
Pack parcel above non-foldable gate	Close cage with a non-foldable gate and continue to add parcels afterward by putting them over the top of the gate. Cage can be packed to different degrees of considered "finished" when this occurs.	Minimize risk of parcels falling when packing.	Avoid extra work if parcels would fall out.	Overload and injuries (mainly top of the back, shoulders, arms and head) can occur due to high lifts.	Use foldable gates to secure the parcels already packed to be in place and enable better physical ergonomics for workers by reducing high lifts. Decreasing risk of parcels falling by enabling more stable packing of parcels.
			Avoid injuries of falling parcels for the worker packing the parcels.	Increased risk of parcels falling from the cage later in the process.	
Ski-slope building of parcels	Occurs when cage is built by packing from the furthers in of the cage and towards worker in a way that resulting in parcels not able to be stacked in the front leaving lot of space. Resembling a ski-slope.	Packing of parcels not optimal.	Lack of knowledge of worker for how to pack a cage optimal.	Increased risk of parcels falling from the cage later in the process (due to unstable packing enabling parcels to fall inside the cage when the cage is transported).	Educate workers with a clear strategy of how to pack parcels in an optimal way to reduce the risk of falling parcels.
			Pressure of time (especially for new and inexperienced workers)	Poor utilization of cage leads to more costs (due to more cages needed).	Reduce stress for the workers.
Re-packing of parcels	Done when a new parcel fits better into a space in the cage than the existing one due to external reasons, like weight or size of parcel. The parcel is put either at another place in the cage or beside the cage in waiting for a better place for the specific parcel.	Better fit of parcel to utilize more of the cage.	Lack of knowledge for how to pack a cage optimal in first step (before re-packing of cage).	More lifts lead to worse ergonomic risk.	Sometimes it can be better to start packing in a new cage instead of re-packing an old one (e.g. for large and heavy parcels).
	Can occur when a parcel cannot be put in the cage due to external reason or in a way fitting the worker's strategy for packing the cage.	If cages has not been packed in a good way from start the worker needs to re-pack it.	Time aspect when packing first time - prioritize personal time or pressure of time.	Extra time needed.	Reduce stress for the workers.
	Can occur if current parcel in the cage is not placed in a stable way.	Let go of parcel in air before stable in cage, not ensuring good fit of parcel.	Comfort reason when packing first time	Poor utilization of cage.	Educate workers - ergonomically worse to re-pack parcels afterward.
			Increased risk of parcels falling from the cage later in the process if it is not re-packed.		

E

Posture aspect motivation

Low zone: In the Low zone the worker normally has to bend and turn his/her neck to place the parcel correctly in the cage. To find and place the parcel correctly in the cage the worker's neck has to be bent downwards and periodically turned. The back is normally bent to be able to put down the parcel, and sometimes turned. An addition to the back is the low freedom of movement when putting down a parcel in the cage, especially when the worker has to take a step into the cage to perform the placement. When putting the parcel in the Low zone the hand is normally under the knee-level since this is the definition of the Low zone. The arms are often/normally outside the range of $3/4$ arm distance when the parcel is put down. General for all the zones is that the leg space sometimes is restricted, especially when worker has to take a step into the cage to be able to place the parcel. Altogether the Low zone posture will receive level 3 of severity.

Medium zone: The neck and back of the worker are periodically bent and turned when putting a parcel in the cage. The low freedom of movement is the same as for the other zones as well as having the arms reached out to more than $3/4$ of the arm length. Compared to the other zones, the Medium one is less critical and will result in a severity of level 2.

High zone: The high zone is similar to the Low zone with the difference that the neck is bent upwards instead of downwards and the hand is above the shoulder height instead of below the knee height. Another exception is that the back is not bent or turned as often, but rather periodically when the worker has to reach far into the cage or in other cases difficult placements. The high zone rates level 3 of severity.

F

Cage flag - identified problems

The appendix presents problems found in the interviews and observations regarding the Cage flag, the reasons why it occurs and what it might lead to.

Problem	Reason to why it occurs	Leads to
<i>Wrong cage flag is put on cage</i>	Inattention from worker (Cages to several destinations can be close to each other, especially for the smaller districts)	Cage arriving to wrong terminal
<i>Several cage flags on cage</i>	Inattention from worker (Old Cage flags are not taken away)	Cage arriving to wrong terminal (if worker only sees the wrong cage flag)
<i>Unique barcodes for each Cage flag</i>	-	Need to scan each Cage flag individually - takes time
<i>Cage is put at wrong line</i>	Inattention from worker	If driver does not double check Cage flag it is transported to wrong terminal

G

Weight calculations of the new parcel-cage

G.1 Theoretical weight test

The average weight of the current parcel-cage is calculated for each of the terminals. The volume change is 31 % less for the new parcel-cage, thus the average weight for the current cage is multiplied with a factor of 0,69 to get the average weight of the new cages.

	Average parcel weight [kg]	Average parcels per cage (current)	Weight of empty cage (current)	Average weight (current) [kg]	Average weight (new) [kg]
The large-sized terminal	3,41	49,6	49	218,1	150,5
The medium-sized terminal	3,84	49,6	49	239,5	165,2

G.2 Real weight tests

40 measurements of weight were taken on the current parcel-cage when it was ready for further transport are shown in the table below. The average weight of the current cage was calculated to be 288,6 kg. The volume change is 31 % less for the new parcel-cage, thus the average weight for the current cage is multiplied with a factor of 0,69 to get the average weight of the new cage. The average weight of the new cage would be; 199,2 kg.

Weights

328	275	251	266
365	189	256	314
207	421	307	364
287	288	370	263
302	335	266	237
325	240	225	309
273	311	262	326
211	283	323	202
297	272	315	199
300	206	415	361

H

Consequence Analysis

The consequence analysis is divided into two parts, the first one concerns work tasks in Terminal 1 and the second one concerns work tasks between terminals and at Terminal 2.

Positive effect Sub-goal:	Unchanged effect Work task:	Negative effect Function/Aim of work task:	Responsible worker	Risks/Consequences with alternative cage change	Effect of risk	Reason	Dependent on factor:	Comment:
Prepare conveyor belt (outlines)	Put empty parcel-cages at outlines	Enable packing of parcels	Terminal worker (T1)	This step does not change				Assume numbers of cages at start to be the same as currently
	Put on Cage flag and scan it in the Cage app and fill in list over how many cages that are sent	Enable parcels to be transported to correct T2	Terminal worker (T1)	Needs to be done for more cages	Increased time	More cages needed for transport	Number of cages in total	This will be done one time per cage
Sort and pack parcels	Fetch parcel from conveyor outline	Enable parcel to move further in process	Terminal worker (T1)	This step does not change	Better ergonomic	Reduce height of lifts + less distance for parcels to fall and hurt workers or damage itself	Height of alternative cage	See ergonomic evaluation of alternative cage
	Pack parcels in the correct parcel-cage	Enable parcels to be transported to correct T2	Terminal worker (T1)	Lower height of cage				
Change cages	Close parcel-cage with gate	Hinder parcels to fall out of cage during transportation	Terminal worker (T1)	Needs to be done for more cages	Increased time	More cages needed for transport	Number of cages in total	Time requirement will increase by 44 %
	Transport cage to buffer with ready cages	Hinder parcels to fall out of cage during transportation	Terminal worker (T1)	Lower height of cage/gate	Better ergonomic	Reduce height worker has to reach for conducting activity	Height of alternative cage	Might be a bit more repetitive work, but better from posture aspect
	Transport empty parcel-cage (from empty cage buffer) to outline	Enables process to continue	Terminal worker (T1)	Needs to be done for more cages	Increased time	More cages needed for transport	Numbers of cages in total	Time requirement will increase by 44 %
	Put on Cage flag and scan in the Cage app and fill in list over how many cages that are sent	Enables process to continue	Terminal worker (T1)	Needs to be done for more cages	Increased time	More cages needed for transport	Numbers of cages in total	Time requirement will increase by 44 %
	Close parcel-cage with gate	Hinder parcels to fall out of cage during transportation	Terminal worker (T1)	Needs to be done for more cages	Increased time	More cages needed for transport	Number of cages in total	Time requirement will increase by 44 %
Prepare cage for further transport	Print out Transportation document	Enables haulage contractor to get paid and enables T2 to know how many cages that are transported to their terminal during the night	Terminal worker (T1)	This step does not change	Better ergonomic	Reduce height worker has to reach for conducting activity	Height of alternative cage	Might be a bit more repetitive work, but better from posture aspect
	Give transportation document to driver	A step in giving over the responsibility. Driver knows how many cages that is transporting	Terminal worker (T1)	This step does not change				Only written number of parcel-cages transported on the paper will change
	Scan transportation document	Driver initiate process of transporting cages to T2	Truck driver	This step does not change				
	Alt. 1: Terminal worker load cage to agreed place Alt. 2: Driver picks cage up at outline/buffer of ready cages	Enables transportation of cages to T2	Terminal worker (T1) Truck driver	Needs to be done for more cages	Increased time	More cages needed for transport	Number of cages in total	Time requirement will increase by 44 %
Transfer cage-responsibility to driver	Driver takes over responsibility for cages	When a set of activities has been performed the truck driver takes over responsibility of the cages to transport them further	Truck driver	This step does not change	Increased time	To be able to put a second layer of cages above the first	Numbers of cages in total divided by 3	3 cages can be put underneath bars and 3 above. 2 bars are used for this.

