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RFID tags, GPS trackers, and how they can benefit Original Equipment Manufacturer's packaging flow

Master’s Thesis in Supply and Operation Management

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Abstract

The use of smart packaging solutions has increased during the past years where the track and trace technologies have made the packaging easier to track and contributing to a more efficient supply chain. The usage of an RFID tag or GPS tracker attached to a company's assets such as packaging has increased. Together with a good information sharing between actors in the supply chain the knowledge of where everything can be used for more accurate planning in the operations at the actors.

There are companies within the automotive industry that own their returnable packaging. One of them is the OEM company that the researchers for this research have been working with. For this thesis, the aim has been to get an understanding of how RFID tags and GPS trackers can be beneficial for an OEM company if the technology was attached to the OEM´s returnable packaging.

In order to fulfil the aim, the researchers have done study visits at the different actors to understand the working processes at each actor. Furthermore, interviews with employees at the actors have been made in order to get their views on their work and if they could see if the track and trace technology can be beneficial for them or not. The findings from the study visits were later analysed together with the literature about packaging, track and trace technology, and material flow. From the analysis the researchers state the results and after the conclusion in order to answer the aim. It was shown that track and trace technology can be beneficial for the OEM company however, more investigation is needed to know which type of technology is the best for what packaging type.

Keywords: *RFID, GPS, Track & trace technologies, Returnable packaging, Material flow, Information sharing.*

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Gabríela Carmen Albertsdóttir & Pernilla Starman, June 2019

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1. Introduction

This research is in collaboration with an Original Equipment Manufacturer (OEM) where the focus is on how track and trace technologies, such as RFID tags and GPS trackers can impact the flow of packaging at the OEM and how it can be beneficial in the flow. The following chapter contains a background of the problem and empirical background of the OEM together with the aim and delimitations.

1.1 Background

Packaging plays a big role in the whole supply chain (Regattieri & Santarelli, 2013). It makes it easier to load a truck, protects the goods, and informs what is inside the packaging, its destination, origin and so forth (Schaefer & Cheung, 2018). Steenis et al. (2017) state that the design of the packaging has a big impact on transportation and storage. The size and the shape need to be adapted to both the goods that are within the packaging and also to the storage facilities and transportation modes, in order to use the space as efficient as possible (Steenis et al., 2017). Other aspects that need to be taken into consideration when working with packaging solutions are, among other things, ergonomic aspects that impact the way of working, environmental aspects and even the disposal of packaging as that can influence the packaging development (Han, 2014).

Through the past years, the possibilities with the packaging solutions have increased where smart packaging has been evolving, and it is expected that the global demand for electronic smart packaging will grow over the next decade (Schaefer & Cheung, 2018). Schaefer and Cheung (2018) define smart packaging as packaging systems where a sensor is integrated into the packaging in order to display information about the quality and improve both product and customer safety. According to Yam, Takhistov, and Miltz (2005), smart packaging increases the possibilities of the packaging system where it enables intelligent functions such as detecting, sensing, tracking and communicating, to provide information, improve quality, and enhance safety and possible speed up the detection of potential problems.

In the supply chain, it can be difficult to get a good quality of tracking goods (Foster et al., 2006). One tracing technology that has been used for many decades is RFID (Foster et al., 2006). RFID stands for Radio Frequency Identification and is defined as a wireless chip that communicates via radio frequency (Perret, 2014). The RFID technology has the ability to trace parts from raw material to finished products, throughout the supply chain, and therefore should enhance the overall supply chain productivity, i.e. if good information sharing through the supply chain is in place (Zelbst et al., 2010). Kong and Yu (2018) explain that there are three different types of RFID tags, which are passive, active and semi-active. Another device that is used as a

tracking function is a Global Positioning System (GPS) tracker. This device enables real-time navigation tracking, which, according to Stefansson and Lumsden (2008), can identify how much packaging is being transported in the system and also minimise the risk of loading or unloading the wrong goods. Tracking the packaging is also very important in case of lost or stolen packaging (Gnimpieba et al., 2015). Apart from tracking the packaging, the material inside the packaging can be tracked and traced as well. That can be beneficial for the receiver of the material as he could then monitor and estimate the arrival time of the material (Zelbst & Sower, 2016). If used in an effective way, these devices can improve the whole information sharing from the supplier to the final assembly and therefore contribute to higher performance in the supply chain (Zelbst, Green, Sower & Baker, 2010).

1.2 Empirical background

The OEM is a global automotive company with many facilities. The OEM has its own packaging that is used to transport material from its suppliers to its factories. They divide their different packaging into two groups; standard and special packaging. Standard packaging consists of wooden pallets and plastic boxes. Both wooden pallets and plastic boxes come in many different sizes in order to have high flexibility for the usage of the standard packaging, meaning, to be able to use the packaging for as many different product families as possible. The designs of the packaging have more or less looked the same for many years and the OEM are questioning if the current packaging is the solution in the future, especially with the development of the technology, such as track and trace devices. The special packaging is developed for specific parts or product families and is used when standard packaging is not suitable, depending on ergonomics, quality, safety, size and more. This results in that special packaging has many different sizes and shapes. One type of special packaging are metal racks and the focus in this research has been to look into these metal racks, together with wooden pallets and plastic boxes.

The OEM's packaging flow that was studied in this research consists of a packaging terminal, material supplier, cross-dock terminal, plant, and transportation company. At the packaging terminal, all packaging is stored and maintained until it is needed at the material supplier. When the material supplier needs the packaging, it is sent from the packaging terminal with the transportation company to the material supplier. The material supplier places its products in the packaging and sends it to the plant. Once the packaging has been used at the plant and is empty, it is transported back to the packaging terminal and stored there until it is needed at the material supplier again.

In addition to transporting goods between two points in the supply chain, the packaging is also used for storage of material in the warehouse, supermarket, kitting stations and assembly lines in the OEM's plants. Therefore, restrictions such as ergonomics, weight, size, and material are put on the packaging, which makes the packaging process more complex. Another complexity in the

packaging flow is the lack of information that the OEM has regarding the amount of packaging that is located throughout the supply chain. This increases the uncertainty of how much packaging is needed in order to have enough amount of packaging in the packaging flow.

The OEM has been working on projects where they are looking into RFID tags and GPS trackers in order to see if the technologies can be used in the supply chain. From this research, the OEM wanted to know more about how these tracking technologies, together with packaging, can be beneficial in the supply chain. The benefits that can be brought in the supply chain, could then lead to lower cost. However, the focus in this research was not primarily on lowering cost, but to analyse if there were any unnecessary steps that could be eliminated or working processes that could be improved in the packaging flow with the use of the technologies.

1.3 Aim

The aim of this research is to identify how the OEM's packaging flow can benefit from RFID and GPS technologies in terms of track and trace.

1.4 Research questions

In order to answer the aim of this research, the packaging flow has been divided into different parts; packaging terminal, material suppliers, cross-dock terminal, plant and transportation companies, where each part in the flow needs to be taken into consideration. Since the packaging terminal, material supplier, cross-dock terminal, plant, and transportation companies are the main actors in the packaging flow, the main focus has been on them and how they handle the packaging. Information about each part in the packaging flow was then used to see how the different tracking devices can be beneficial in the overall packaging flow. The research questions are therefore focusing on the different parts, i.e. the packaging terminal, material suppliers, cross-dock terminal, plants, and transportation companies, in the packaging flow.

1. *How can RFID tags and GPS trackers, attached to a pallet, box or rack, be beneficial at a packaging terminal?*
2. *How can RFID tags and GPS trackers, attached to a pallet, box or rack, be beneficial at material suppliers?*
3. *How can RFID tags and GPS trackers, attached to a pallet, box or rack, be beneficial at a cross-dock terminal?*
4. *How can RFID tags and GPS trackers, attached to a pallet, box or rack, be beneficial at an OEM plant?*
5. *How can RFID tags and GPS trackers, attached to a pallet, box or rack, be beneficial at transportation companies?*

1.5 Delimitation

The delimitation for this thesis was to analyse the packaging flow in Sweden, due to the different actors are located in the same geographical area. Additionally, the OEM is located all over the world so it would be difficult to cover all geographical areas within the time frame given for this research.

2. Methodology

This chapter will explain the methodology used in order to fulfil the aim of this research. First, the research strategy that was used in the research is presented, followed by how the literature review, data collection, and analysis was conducted. Secondly, an explanation of how reliability and validity were addressed is presented. Lastly, ethical principles are presented.

2.1 Research strategy

Data collection can be performed in two different ways; quantitative and qualitative approaches (Bryman & Bell, 2015). A qualitative approach is described as an approach where the emphasis is rather on words than quantification when collecting and analysing data (Bryman & Bell, 2015). Hanson et al. (2011) explain the importance of performing a qualitative approach in an everyday environment to see the work task from the participant's point of view, but also the disruptions that can occur. Bryman and Bell (2015) continue by stating that there are other ways to collect information with a qualitative approach. The methods Bryman and Bell (2015) describe are ethnography i.e. participant observation, qualitative interviews, focus groups, language-based technique when collecting qualitative data and analysing text and documents in a qualitative approach. However, a qualitative approach is sometimes criticised to be too subjective (Bryman & Bell, 2015). Bryman and Bell (2015) also state that a quantitative approach is divided into four parts such as measurements, causality, replications, and generalisations. In other words, it is focusing more on numerical data that can later be compared to theory (Bryman & Bell, 2015). Choosing one of the methods is usually the most common thing to do, however, according to Leech and Onwuegbuzie (2009) there is a third alternative and that is to mix quantitative and qualitative approach. By collecting different types of data, it is possible to combine the accuracy of quantitative data with the complex perceptions from the qualitative approaches (Bryman & Bell, 2015). The aim of the study was to analyse the packaging flow and if the track and trace technologies could be beneficial for the packaging flow. Therefore, a qualitative approach was seen as more suitable as a research strategy, although some parts of a quantitative approach were used.

Two other approaches of data collection in research are deductive and inductive approaches. The deductive approach is the most common approach where theory is analysed at the beginning of the study and research and data collection is conducted based on the theoretical considerations. The inductive approach is, on the other hand, the opposite, where the theory is the outcome of the research, i.e. observations and data collection is performed at the beginning of the study and assumptions are drawn out from the observations (Bryman & Bell, 2015). Bryman and Bell (2015) also state that a combination of these two approaches is called an iterative approach, where the researcher moves back and forth between the theory and data collection. The research mainly comprised of an iterative approach. At the beginning of the research, the literature was

analysed and based on the theoretical considerations, the design of the research was conducted. Then, the process of gathering data commenced where the data collection was based on interviews and analysis of the packaging flow in the plants. However, after having commenced the data collection process, additional ideas regarding literature to analyse came up that the researchers had not thought about before, which lead to that additional literature was analysed. That later helped the researchers to finalise the data collection, and later on, some additional questionnaires were sent to the interviewees that the researchers considered they needed additional information from. Figure 1 describes the research process that was used in this research.

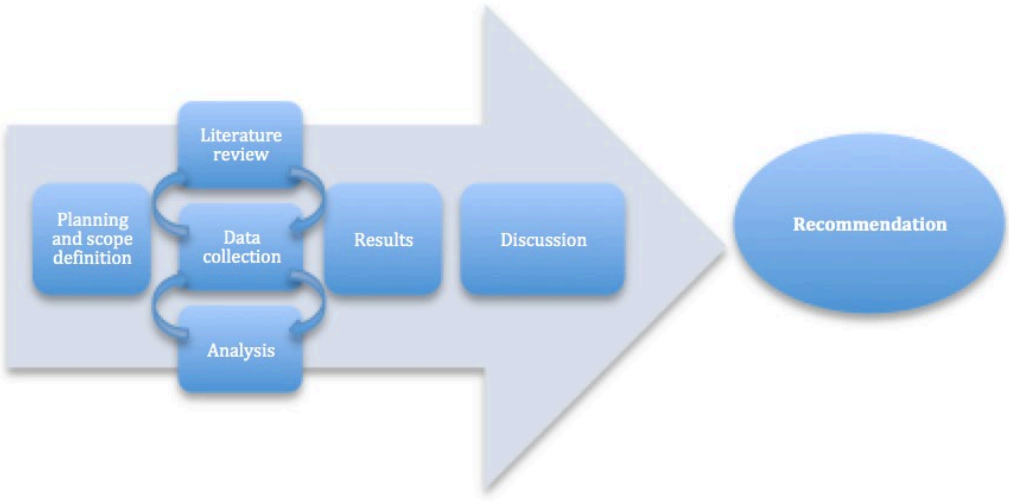

Figure 1. *The research process.*

2.2 Data collection

Data collection is the key factor of any research project and can be performed in several ways (Bryman & Bell, 2015). The main purpose of data collection is to compile enough information in order to be able to answer specific research questions (Bryman & Bell, 2015). The data collection that was done in this research comprised of a literature review, interviews, site visits, and questionnaires that were sent to participants by email. Both primary and secondary data were collected during the data collection process. Primary data is described as data that is collected for the first time, while secondary data has been collected before by someone else (Kothari, 2004).

2.2.1 Literature review

In order to get good knowledge and a deeper understanding of the research topic, a literature study was performed. Various articles, descriptions and case studies about track and trace technologies were studied in order to build more compelling theory findings, as that creates a more robust study according to Dubois and Gadde (2014). By reviewing the accessible literature, it helps the researcher in finding which theory is relevant for the research and which is not.

The literature has been narrowed down to smart packaging, including RFID tags and GPS trackers, and how to relate these technologies with the information flow in the supply chain. The tracking technologies were identified and investigated separately from packaging in order to study how they could be used in different situations. Additionally, it brought input to what has been developed regarding smart packaging and different tracking technologies. This was done in order to draw conclusions at the end of the research. Literature about material flow and packaging's role in the material flow was analysed as well as packaging in general. Later, the literature was compared with the empirical data that was gathered to get a better understanding of how to relate the literature with reality and if it is aligned to the reality or not.

According to Bryman and Bell (2015), electronic databases are the most common way to use when doing a literature study. In this research mainly electronic databases were used to gather different types of literature. These electronic databases are Chalmers Library and Google Scholar and some of the search words that were used were: *RFID, GPS, track and trace technologies, opportunities with RFID/GPS, challenges with RFID/GPS, packaging, returnable packaging, material flow, information flow, information sharing.*

2.2.2 Interviews

Interviews can be performed in three different ways; structured, semi-structured and unstructured interviews (Bryman & Bell, 2015). A structured interview is performed with the goal to give all interviewees exactly the same questions according to Bryman and Bell (2015). The authors state that the answers from the interviewees could then be aggregated but only if the respondents have received the questions the same way. When a semi-structured interview is used, a number of general questions are asked (Bryman & Bell, 2015). In a semi-structured interview, the interviewer can ask further questions to the replies in order to get a deeper knowledge about that specific part (Bryman & Bell, 2015). An unstructured interview, however, is described as an interview were the interviewer many times has a list of topics that he or she would like to discuss (Bryman & Bell, 2015). Bryman and Bell (2015) continue by explaining that an unstructured interview will have different outcome due to that the structure of the interview can be different from the interviews. The interviews that were conducted during this research have all been either semi-structured or unstructured, and detailed notes were written down during each interview.

The notes were later sent to the interviewees for validation and they could then correct the answers if needed. The interviewees that were interviewed are listed in Table 1 below.

Table 1. *Interviews and site visits that were performed during the research.*

Activity	Company	Work title
Interview	OEM	Process Manager
Interview	OEM	Internal Logistics Development Manager
Interview	OEM	Internal Logistics Development Manager & Process Manager Handle Material
Interview	OEM	Innovation Manager
Interview	OEM	Process Manager
Interview	OEM	Internal Logistics Development Manager
Interview	OEM	Price Manager & Strategic Packaging Planner
Interview & Site visit	OEM – Plant 1	MTS Internal Logistics & 2x Internal Logistics Development Managers & ME, Internal Logistics, MTS
Interview & Site visit	OEM – Plant 1	Internal Logistics Development Manager
Interview & Site visit	OEM – Plant 2	Global Logistics Specialist
Interview	OEM	MTM Internal Logistics & ME, Internal Logistic & EXT, Consultant
Interview & Site visit	Terminal & Cross docking terminal	Process Development Manager
Interview & Site visit	Supplier 1	Logistic Packaging & Logistic Manager
Questionnaire	Supplier 2	Team Leader SCM
Questionnaire	Transportation company 1	Process Development Manager
Questionnaire	Transportation company 2	CEO
Interview	Smart technology company	CEO / Customer Success Manager

Interviews with employees at OEM

There has been a number of interviews with employees at OEM. Several employees that were interviewed were chosen due to the fact that they were involved in different projects concerning both packaging and track and trace technologies. The interviews began by letting the employees explain what they have done in their projects and what results have been received. After having let the employees introduce their projects and discussed what they have been investigating in their project, then more specific questions connected to the topic of the research were brought up. The employees working closely with the packaging flow were also interviewed where the researchers could ask questions and analyse the packaging flow in more detail together with the employees.

Interviews and questionnaire to material suppliers

Since material suppliers are part of the packaging flow it was important to get their input on having trackers on the packaging. A questionnaire was sent to ten suppliers by email. The suppliers were chosen based on how big volumes of materials they send to the OEM. For this research, suppliers that send high and medium volumes were chosen. The response rate was two out of ten, resulting in that findings from two suppliers were analysed. One of these suppliers (Supplier 1) offered the researchers a site visit at their facilities and take an interview with them there. That was considered helpful, both for the researchers to see their facilities and have a face-to-face discussion as that would enable for more open discussion. The same questionnaire was used for the on-site interview as was sent to the rest of the suppliers through email. The questionnaire included questions where the material suppliers were asked about their thoughts of OEM tracking its packaging, and if they thought the technologies could be useful in their processes when they load the material in the packaging and send to the OEM. One of the suppliers responded by answering the questionnaire through email (Supplier 2). Furthermore, additional questions were sent to both of the suppliers in order to get a better understanding.

Questionnaire to transportation companies

As transportation companies transport the packaging between different actors using the packaging, it was considered essential to analyse them as well. The questionnaire was sent by email to three transportation companies that the OEM use frequently to transport its packaging between the different parts in the flow. Two of the transportation companies answered the questions, giving a response rate two out of three. The asked questions were, for example, if they had customers tracking their own goods at the moment, and what the transportation company thought about letting the customers track the goods without the need from the transportation company. These questions were asked in order to understand their thoughts, concerns or if they were positive to let the customers handle the tracking instead.

Interviews and questionnaire to a smart technology company
In order to get a better understanding of the technologies that are being considered and how they can be used, a company that offers track and trace solutions was contacted. The structure of the interview was unstructured where the interviewee could explain how the different solutions function and how they can be beneficial with the research focus in mind. The interviewers then had the opportunity of asking questions about the technologies to get a deeper understanding of how the technologies can be used within the packaging flow.

2.2.3 Site visits

Visits were performed at the OEM's plants located in Sweden, at an OEM's supplier site located in Sweden that uses both standard and special packaging, and also at one packaging terminal that stores empty packaging for the OEM in Sweden. The visits at the plants were made in order to understand how the packaging is used inside the plants. All of these visits lead to an understanding of the OEM's packaging flow, and also how the packaging is used, stored and transported within the different areas. It will also contribute to what the plants and the packaging terminal require of the packaging. By visiting more than one plant, it gave a better overview of how the plants were working and if there were any bigger differences that needed to be taken into consideration. Two of the plants in Sweden were chosen due to the fact that they are relatively close form a geographical point of view.

Site visits were done in both plant 1 and 2. Two visits were done at plant 1, where the first visit was focused on looking into the packaging flow of standard packaging. The standard packaging was followed from the point where it enters the plant until it is used at either the kitting station, supermarket, sub-assembly or assembly line. The walk through the plant was done with two Internal Logistics Development Managers that have good knowledge of the packaging flow. Besides the site visit, discussions with two employees working with internal logistics, which had started two separate investigations with RFID tags, were held. The second visit was more focused on the packaging flow of special packaging, which is slightly different from the standard packaging flow, and on the things that the researchers wanted to get a deeper understanding on from the first meeting. The second visit was done with one of the Internal Logistics Development Manager from the first visit, where he was interviewed as well. One site visit was done at plant 2, where the visit was done in the same way as the visit to plant 1. Both the standard and special packaging flow was followed in guidance with a Global Logistics Specialist. A second visit was not considered necessary at plant 2 as the packaging process within both the plants are quite similar.

A similar site visit was done at the packaging terminal and the cross-dock terminal where the Process Development Manager followed the researchers through the terminals. Both the packaging terminal and the cross-dock terminal are located next to each other and operated by

the same company. Thus, one site visit could cover to analyse the packaging flow at both locations. Another site visit was done at the material supplier, where the packaging flow was analysed from where it enters their facilities until it leaves. Before the walk through the plant, the interviewees were interviewed about their thoughts regarding implementing RFID tags and GPS trackers to the OEM's packaging.

After the site visits, all data was compiled into one document for each visit. The documents were later sent to the employees that guided the researchers through the facilities. When the employees had read the documents, they sent back comments on the texts to the researchers in order to have the correct details in the research.

2.3 Data analysis

Data analysis is a stage in the research that includes several elements and where the raw data has to be managed (Bryman & Bell, 2015). The main task is reducing the large amount of information that has been gathered in order to be able to interpret the material (Bryman & Bell, 2015). When doing the analysis of this research, the researchers compared the data that had been collected from interviews and site visits with the literature that had been gathered. Out from these findings, the researchers made a summary for each research question where they separately listed their overall thoughts on how the track and trace technologies would affect each actor in the packaging flow. After having done that individually, the researchers discussed and compared their thoughts and understandings.

2.4 Quality of the research

One of the criteria for evaluating the quality of research is trustworthiness (Bryman & Bell, 2011). Trustworthiness consists of four aspects that are credibility, transferability, dependability, and confirmability (Bryman & Bell, 2011). Firstly, credibility both ensures that the research has been carried out with good practice and that the researcher has understood the research findings correctly (Bryman & Bell, 2011). To ensure credibility, the researchers discussed the findings from both the interviews and the site visits in order to ensure that the findings were understood in the same way. If there was some doubt or different understanding, the researchers asked additional questions to the interviewees in order to get clarity. In addition to that, a summary of the interviews and site visits were sent to the interviewees in order to have confirmation that the findings were understood correctly. Secondly, transferability ensures that the researcher has made detailed research, which can be seen as a database for making judgments about the feasible transferability of findings to others (Bryman & Bell, 2011). Transferability was not considered in this research as the research is anonymous and transferability was therefore considered difficult as the reader does not know which type of operation the research applies to. Thirdly,

dependability involves ensuring that complete records of all phases of the research process are kept in an accessible manner, such as problem formulation, notes, interview transcripts and so on (Bryman & Bell, 2011). To ensure dependability, the researchers took notes during the interviews and site visits, where they discussed the findings from the interview afterward. Lastly, conformability recognises that complete objectivity is not possible when doing business research. The researcher should not allow personal values or theoretical inclinations influence the conduct of the research and the findings from it (Bryman & Bell, 2011). To ensure conformability, both of the researchers were present at all interviews and site visits to minimise bias of the researchers, and the findings were analysed with that in mind to let personal opinions not affect the conduct of the research.

2.5 Ethical principles

Bryman and Bell (2015) discuss that ethical principles can be broken down into four main areas, which are: *harm to participants, lack of informed consent, invasion of privacy*, and *deception*. Since the research is anonymous, all information of individuals and organisations are maintained as confidential. Thereby, no *harm to participants* was considered in this research. When sending emails to possible participants, the researchers introduced and informed them about the research's purpose and motivation and the reason why they were contacted. The individuals were therefore given a choice to participate in the research. This was done in order to prevent *lack of informed consent* and *invasion of privacy.* However, the answers from the individuals that chose to participate cannot be proven to give the true picture of reality as they might have restrictions on what they are allowed to say from their companies. To prevent *deception,* the researchers clearly informed the possible participants about the focus of the research.

3. Literature review

This chapter presents the literature review for this research. The first section presents the material flow. The second section presents the packaging's role in the material flow. The third section then presents a description of RFID tags and GPS trackers and the opportunities and challenges with these track and trace technologies.

3.1 Material flow

Material flow can be described as the movement of raw material starting from the company's suppliers until its customers (Jonsson & Mattsson, 2009). The ideal flow would be continuous movement of materials, but according to Jonsson and Mattsson (2009), these flows are difficult to be achieved in real life, due to interruptions between the involved value-adding operations. The authors continue by stating that due to this discontinuity and to avoid more inevitable disruptions between sub-flows, the different sub-flows are separated from each other.

3.1.1 Information sharing

All actors belonging to the same supply chain network need to have good communication and coordinate their activities in order to achieve higher efficiency and performance throughout the supply chain (Hunt et al., 2006). When there exist various members in the supply chain, the real-time visibility of demand becomes a big issue and can increase the risk of a bullwhip effect (Véronneau & Roy, 2009). The bullwhip effect refers to when fluctuations in order sequence are greater upstream in the supply chain than downstream (Ouyang, 2007). Information sharing between actors in the supply chain is normally considered to be one of the main reasons to reduce bullwhip effect and add value to the chain (Giard & Sali, 2013; Ouyang, 2007). By having good information sharing, there needs to be some degree of coordination among the supply chain members, which would result in a better allocation of inventories across the supply chain (Ouyang, 2007).

3.1.2 Inventory

In order to integrate the whole material flow system, it is important to have inventory so that materials requirements in production can be fulfilled without delays (Jonsson & Mattsson, 2009). Then, so-called safety stocks are used, where their main role is to prevent shortages that occur due to disruptions and the effects of unpredictable consumption (Jonsson & Mattsson, 2009). When the demand is estimated by the downstream actors in the supply chain based on forecasting, it can lead to inventory fluctuations, which leads to higher levels of safety stock and larger inventory costs downstream in the supply chain (Ma et al., 2013).

3.1.3 Human errors in the material flow

It is often perceived that human errors can be predicted and eliminated but that is not the case as long as humans are a part of the production system (Sandom & Harvey, 2004). Human error can be seen from two different aspects, either the cause or the symptom of a failure (Sandom & Harvey, 2004). Many think that automation of human tasks will decrease the number of human error but that may not always be the case since the automation creates new human tasks and later new human error (Sandom & Harvey, 2004). However, by making the tasks easier to understand, reducing the stress and discomfort, increase job and team design, adapting the workload for the worker, the human error can be more controlled (Sandom & Harvey, 2004). Human error should be taken into consideration when implementing a safety assessment and investigating accidents but it becomes more difficult to estimate the human reliability because of dynamics and complexity with socio-technical setups (Rong, Tian & Zhao, 2016).

3.1.4 Packaging's role in the material flow

Packaging has a big effect on the logistics performance of the whole supply chain (Pålsson, 2018). By using suitable packaging, supply chain cost and environmental impact can be reduced (Pålsson, 2018). Moreover, the packaging protects the material inside the packaging as it travels throughout the supply chain (Pålsson, 2018). Packaging also carries information such as product information and data used for track and trace through the supply chain and this information is communicated with the actors in the supply chain with the help of identification technologies and labels (Pålsson, 2018).

Despite its importance, the packaging is often seen as an unnecessary cost due to its unknown or not fully considered functions that it has to perform (Livingstone & Sparks, 1994). The cost of packaging mostly includes material costs and labour costs, though many logistics costs are also impacted by packaging (Chan et al., 2006). Damages, control, cargo handling, and warehousing costs are all affected by the quality and performance of the packaging as well as risks (Chan et al., 2006). By improving the efficiency and effectiveness of the packaging design, it is possible to save costs in the supply chain. This lower cost can improve both the service value and product value (Chan et al., 2006).

Pålsson (2018) defines packaging when it is part of a coordinated system that prepares the material inside the packaging for transportation, distribution, retailing, storage, and end use, and when it ensures safe delivery to the final consumer in flawless condition at minimum cost. As the packaging travels between different partners in the supply chain, it is important that the packaging design and use of packaging meet the demands of all the partners to increase the effectiveness of the whole system (Chan et al., 2006). However, there is a lack of conformity between different partners in several material flow systems, especially when there are different demands on the packaging by different partners in the system. This can lead to additional costs

due to a need for repacking, extra administrative costs and delays of the materials being transported (Chan et al., 2006).

The importance of packaging has increased with the growth in information technology usage, automation in warehousing, and material handling as the packaging can be used more efficiently (Livingstone & Sparks, 1994). Packaging has a big impact on the layout and design of a warehouse and the overall productivity of the warehouse (Livingstone & Sparks, 1994). To be able to have efficient storage, packaging dimensions and stackability are important factors (Livingstone & Sparks, 1994).

Returnable packaging

The main reason for companies choosing to use returnable packaging is the potential for cost savings (Gustafsson et al., 2013). When using returnable packaging, the packaging containing the material is sent from a sender to a recipient, and after that, the packaging is transported from the recipient to another sender (Kroon & Vrijens, 1995). Apart from transporting the packaging, the returnable flow system also involves cleaning and maintenance of the packaging, as well as storage and administration (Kroon & Vrijens, 1995). One issue with returnable packaging is that the packaging does not always return back to where it is supposed to be reused (McKerrow, 1996). This, because the returnable flows are difficult to monitor and control due to many drop points, where the cost of investigating the non-returnable packaging might be higher than the value of the packaging itself (McKerrow, 1996).

There are many types of packaging that can be used in a returnable packaging flow. Two of them are wooden pallets and plastic boxes. Pallets that are used to transport material are produced in many different sizes and of different types of material such as wood, plastic, and metal (Amin et al., 2018). Wood is the most commonly used according to Amin et al. (2018). This due to the fact that the wooden pallet is very cheap compared to the other types of pallets because it has a low production and material cost (Amin et al., 2018). The plastic boxes are reusable and can be stacked if there is a lid on each box. This type of box is defined as a Nestable container (Pålsson, 2018). The lid on the box is used both in order to be able to stack boxes with the material but also to protect the material from grime (Pålsson, 2018). Information on what the box contains is often presented on a label, sealed on the box (Pålsson, 2018).

3.2 Track and trace technologies

Track and trace technology enables monitoring and recording of shipment movements from the place of origin to its destination. One of the main advantages of the track and trace technology is the ability to detect an item's location, to know the distribution history of items, and know the exact item quantities in stock (Véronneau & Roy, 2009). This can add real-time visibility to items travelling through the supply chain with minimal direct physical contact with the items

(Véronneau & Roy, 2009). By having this technology in place and thereby having the capacity to streamline the distribution process to all relevant actors in the supply chain, there is a potential for increased overall efficiency since work duplication and redundancy can be reduced (Véronneau & Roy, 2009). However, it is dependent on the business how detailed the tracking is needed. For one company it might be sufficient to know that a shipment is between point A and B, while another company requires precise geographic information all the time (Roos et al., 2005). The track and trace technologies (RFID tags and GPS trackers) provide different information in the supply chain (Lam & Ip, 2019). While RFID technology provides discrete information about certain items at certain locations, such as the origin of the item, its production data and location, the GPS technology uploads real-time information and accurate positioning of an item via cellular or satellite networks (Lam & Ip, 2019).

3.2.1 Radio Frequency Identification

An RFID tag is a small item that can both be attached to or integrated into a product and can provide the same information as a label (Véronneau & Roy, 2009). An RFID tag consists of both a microchip and an antenna (Angeles, 2005). The microchip stores information, such as an item's serial number, while the antenna enables the microchip to transmit the information about the item to a reader. The reader then converts the information on the RFID tag to a form that is understandable by computers (Angeles, 2005).

Environment aspects

There are several types of RFID readers and they work different compared to in which kind of environment they operate in. Some readers work better in a dense environment where various tags are stacked on top of each other, while other readers are more user-friendly (Zelbst & Sower, 2016). Therefore, it is important to be aware of the environment that the reader will operate when implementing RFID technology (Zelbst & Sower, 2016).

Frequencies

Another factor to take into consideration is that RFID readers operate at different frequencies. There are three different frequencies, low, high and ultra-high (Kazim, 2010). Tags that function in low frequencies (<135 kHz) are more preferable when the tags need to operate near water or metal as the reading distance of the tags is short (Kazim, 2010). A tag that is functioning on high frequencies (13.56 MHz) is suitable when there are many tags that need to be read at the same time, over a longer distance, and relatively fast (Kazim, 2010). For these tags, the signal is more sensitive for having metal objects around it (Kazim, 2010). The tags operating at ultra-high frequencies (between 850 and 960 MHz) are good on sending large amounts of data over long distances, however, the signal can have difficulties with getting through many materials (Kazim, 2010).

Active, passive and semi-active tags

RFID tags can be active, passive, or semi-active. Active tags contain a battery that powers the microchip's circuitry and sends signals to the reader (Angeles, 2005). They use signal strength for locating and have the ability to transmit signals over long distances (Kong & Yu, 2018). However, they have poor anti-interference and low location accuracy (Kong & Yu, 2018). An active tag has a shorter life than a passive tag as the power source will eventually get empty (Zelbst & Sower, 2016). As more information is stored on the tag, the shorter the lifetime of the tag be (Zelbst & Sower, 2016).

Opposite to active tags, passive tags do not contain a battery. Instead, they are powered by electromagnetic waves that the reader sends out in order to induce a current in the antenna (Angeles, 2005). Passive RFID tags have high positioning accuracy where the positioning mostly uses the signal arrival time, signal arrival time difference, and signal arrival angle (Kong & Yu, 2018). Passive RFID positioning is however not suitable for long-distance indoor positioning due to the working distance is rather close, which makes the positioning accuracy easily affected by obstacles (Kong & Yu, 2018). The unit price of a passive tag is relatively lower than that of an active one, making the passive tag a better option for distribution supply chain applications (Véronneau & Roy, 2009). Passive RFID systems can use low frequency, high frequency, and ultra-high frequency. Low and high frequencies are generally used for security reasons, while ultra-high frequency is mainly used for inventory management. (Zelbst & Sower, 2016).

Semi-active tags can be seen as a combination of active and passive tags. They both use a battery and electromagnetic waves that the reader sends out (Angeles, 2005). They use low frequency within a close range in order to be activated but the tag can be identified on a long distance with a high frequency (Kong & Yu, 2018). The advantages of semi-active RFID technology are strong controllability and good anti-interference (Kong & Yu, 2018). The semi-active positioning accuracy is high, and the indoor positioning has a long distance, leading to a high development potential (Kong & Yu, 2018). Both semi-active and active tags are normally used for goods of high value that are scanned over greater distances (Angeles, 2005).

Read only and writable RFID tags

The RFID tag includes a chip that is either read-write or read-only. Read-write chips are much more expensive than read-only chips. These chips are used for product items that are of higher value. On the other hand, it is more common to use read-only chips to track inexpensive items (Véronneau & Roy, 2009). According to Sen, Sen and Das (2009), the difference is that the read-only tag is programmed at the tag manufacturer, meaning that the tag has one identification number from the manufacturer until the tag is not functioning anymore. The authors continue by stating that if the user of the tag would like to store more information regarding the item that the tag is connected to, that has to be stored in the database at the user. The read-write tag allows the user to write and rewrite the tag during the time it is used due to an extra memory in the tag (Sen,

Sen & Das, 2009). An example of how a read-write tag can be used is when a tool used at an assembly line needs maintaining, the tag can be updated with the name of the technician when the tool has been checked out (San, San & Das, 2009). The read-write tag is updated with the RFID reader the technician uses (San, San & Das, 2009). There are some tags called write-once, meaning that the user can write one time when it arrives from the tag manufacturer (Sen, Sen & Das, 2009). An RFID reader can update the tag if it is a read-write tag and the read data can be sent to the applications the user use (Sen, Sen & Das, 2009). The data goes either directly to the application or through an RFID middleware (Sen, Sen & Das, 2009). There are different qualifications of RFID readers, some can communicate with tags operating at different frequencies but there are also readers that can read both an RFID tag and a barcode (Sen, Sen & Das, 2009).

3.2.2 Global Positioning System

GPS is a good solution for tracking the location of a packaging (Kirch, Poenicke & Richter, 2017). Timing is highly important in telecommunication systems today and GPS is more and more used to synchronise the elements of networks (Misra & Enge, 2006). The real-time synchronisation enables the transponder's location to be tracked with almost no time-delays (Roos et al., 2005). Lam and Ip. (2019) mention that the real-time position given by a GPS tracker can be used in order to increase customer service, decrease costs, and increase safety during transportation.

GPS trackers normally use satellites to track the exact latitude and longitude of a transponder (Roos et al., 2005) and each GPS satellite transfers a microwave radio signal that consists of two carrier frequencies modulated by a navigation message and two digital codes (El-Rabbany, 2002). A vehicle that is tracked includes a transponder for the tracking to take place. The satellite then tracks the transponder's location and passes the information on to a base station, which sends the information forward to an information system that is connected to the Internet (Roos et al., 2005). An antenna is required, either internally or externally, with the use of a GPS receiver (El-Rabbany, 2002). The antenna then receives the incoming satellite signal and converts it into an electric current that can be handled by the GPS receiver (El-Rabbany, 2002).

3.2.3 Opportunities with RFID tag and GPS tracker

Zelbst and Sower (2016) mention several benefits when using an RFID tag in the supply chain. These benefits can, for example, be improved asset visibility, reduced stockouts, real-time decision-making capabilities, improved reverse logistics, and prevention of obsolescence.

Labels

An RFID tag can give more track and trace information than a label and offer a better supply chain visibility (Pålsson, 2018). The main idea behind the RFID technology is to move from line of sight scanning of a barcode system to a proximity scanning through radio frequency (Véronneau & Roy, 2009). One benefit with RFID tags is that the time that it takes to read them is much less than the time it takes to read barcodes for example (Zelbst & Sower, 2016). Many tags can then all be read simultaneously instead of sequentially when reading the barcodes. The RFID tag utilisation allows members of the supply chain to capture customer information directly into the supply chain database without human intervention (Zelbst et al., 2010). It is considered to have great advantages over the ordinary barcode, which requires a scanner to read the barcode directly in front of it and can be unreadable if the paper label gets damaged (Angeles, 2005).

Locations

It is beneficial for companies to use GPS tracking system as it shows the real-time location of an item that helps to eliminate wasteful activities (Misra & Enge, 2006). In addition, it enables companies to be more productive in their operations by providing highly accurate position information (Misra & Enge, 2006; Lam & Ip, 2019). An RFID tag cannot give a real-time location, however, one way of using the RFID technology is to integrate RFID tags with sensor technologies, such as GPS, to facilitate the real-time monitoring of shipments (Zelbst & Sower, 2016). In that case, it can be easier to integrate an active RFID tag rather than a passive RFID tag as the active tag enables reading over longer distances than a passive tag (Zelbst & Sower, 2016; Kong & Yu, 2018).

There are also possibilities to improve yard management systems with the use of an RFID tag and GPS tracker. The RFID readers and GPS sensors mounted on trucks could then track RFID tags placed on containers moving in and out of the warehouse (Maras, 2015). It increases the visibility for both the employees and the customers of the containers' status, whether it is in transit, has arrived at a particular facility, if it has been unloaded or is in the process of being unloaded from a truck (Maras, 2015). A cloud-based, advanced yard management system then automates yard operations, such as check-in, yard moves, and checkout, and provides automatic tracking of assets in order to ensure a continuous update on the yard situation (Maras, 2015). By increasing the visibility into container locations, the operating efficiency will increase, errors and risks will reduce, as customers will have a clear window into the operations (Maras, 2015).

Inventory

With the emergence of real-time networks, the use of RFID technology has gone from tracking tool for inventory and assets, to deliver information about product status reports and inefficiencies in the supply chain (Maras, 2015). The use of RFID technology makes it possible to have faster and more extensive views into potential inventory problems that allow companies

to take preventive actions and thereby reduce the need for expedited delivery of goods (Maras, 2015).

In order to know how the supply chain performs there are different things that are measured, such as capacity utilisation, average product fill rate, response time and profit, according to Hunt et al. (2006). Hunt et al. (2006) mention that the capacity utilisation should be high and at the same time be able to respond to variations in demand in order to grow. The authors continue by saying that the average product fill rate can be enhanced by having a safety stock in order to reduce the risk of stock-out. However, there is a balance between inventory cost and lost profit occurring from stock-outs and by using information collected by RFID tags, the forecast on the demand can be more accurate resulting in lower safety stock (Hunt et al., 2006). The response time can be calculated more accurate when the right information is shared through the supply chain and this can then increase the profit without affecting the customers in a negative way (Hunt et al., 2006). Furthermore, the profit can be increased with for example increasing the loading time of a trailer, resulting in larger shipments and decreasing the transportation cost (Hunt et al., 2006). However, this can affect the customers due to that the response time will be longer (Hunt et al., 2006).

Information sharing

When working with supply chain activities, supply chain managers have many tools to use and an RFID tag is one of them (Hunt et al., 2006). With the help of RFID tag and good communication, information such as location, production, inventory, and transportation can be monitored and used for decision making (Hunt et al., 2006). The RFID tags can carry much more information than the barcode technology, or 10-100 times the data generated in the barcode system (Kapoor et al., 2009). This added capacity enables extra information to be stored, such as location, history and destination data (Véronneau & Roy, 2009).

It is though important to use the RFID technology correctly to get the most benefit from it. It can bring various opportunities for organisations to integrate the use of RFID tag with an ERP software, but even so, the cost of implementing RFID systems in the supply chain can be a big issue (Zelbst & Sower, 2016).

Zelbst et al. (2010) state that in order for RFID technology to improve the supply chain performance, information sharing across the supply chain needs to be in place. That allows real-time information to be distributed throughout the supply chain. Information sharing through the supply chain requires organisations within the chain to share information, mutually and openly, with both suppliers and customers (Zelbst et al., 2010). Furthermore, Information and Communication Technology (ICT) standards can contribute to better information sharing between actors in the supply chain (Pålsson, 2018). These standards will also help to locate the packaging and to follow it throughout the supply chain (Pålsson, 2018).

Table 2 summarises the opportunities stated above. The green colour symbolises what the technologies contribute to, for example, both RFID tags and GPS trackers increase the asset visibility. Furthermore, the red colour symbolises the opportunities that the technologies cannot contribute to. An example is that RFID cannot give a real-time location since it is only possible to see where it has been the last time it was scanned. The yellow colour means that the opportunity can be achieved with the technology, but it will require more resources, for example, to control the inventory with the help of GPS.

Table 2. *Opportunities with RFID tag and GPS tracker gathered from literature.*

Opportunities		
	RFID	GPS
Increase asset visibility		
Real-time location		
Decision-making capability		
Less time for scanning		
Control over inventory		
Enables better information sharing		

3.2.4 Challenges with RFID tag and GPS tracker

According to Kirch, Poenicke, and Richter (2017), the RFID tag is good to identify the packaging and what it contains. The RFID tag also allows the company to track and trace their products on an item level (Kirch, Poenicke and Richter, 2017). However, tracking each individual part inside packaging with RFID tags are in many cases difficult to do since, from a technical point of view, it can be difficult to place the tag on each part but also to read the tag automatically (Kirch, Poenicke and Richter, 2017). In order to use the RFID tags and avoid the difficulties, the most common way is to track the packaging used for shipping the material (Kirch, Poenicke and Richter, 2017).

Global standards

Zelbst and Sower (2016) mention that in order for the RFID tag to reach its full potential in supply chain management, the synergy between countries that have different standards is necessary to have an open set of global standards. The different standards apply to, for example, issues of tags, frequencies, communication equipment, and databases that all have to be

addressed by a global standard. Only the issues of tags is a big obstacle in itself since RFID tags differ between both applications and manufacturers in many ways.

Usually, when integrating an RFID tag with other technologies, the most challenging issues are not technological but rather cultural and legal (Zelbst & Sower, 2016). Nevertheless, firms might have difficulties with evaluating their own needs and determining which activities can benefit from the use of RFID tags and similar technologies (Wamba, 2012). If the data generated by the RFID tags are not used appropriately, it could end up being an expensive barcode system (Kapoor et al., 2009).

Furthermore, there is a difference in how well the tags function depending on where in the world's region that they are located in. An RFID reader for one region does not necessarily work in another region (Zelbst & Sower, 2016). Zelbst and Sower (2016) mention that the world can be divided into three regions that determine the frequencies in each of the regions (see Table 3).

Table 3. *Different frequencies across the world (Zelbst & Sower, 2016).*

Regions	Frequencies
1 (Europe and Africa)	865.6–867.6 MHz
2 (North and South America)	902–928 MHz
3 (Asia Pacific)	No specifications

Environment

With almost every technology, some obstacles might occur. These obstacles can, for example, include metal, liquids, cardboard, or other RFID technologies that are on the same frequencies (Zelbst & Sower, 2016). The metal can reflect or bounce the signal of the RFID tag making it difficult to read the information on the tag, some liquids can absorb the signal so that it does not pass through, cardboard can absorb humidity and thereby making it difficult to read the information on a tag due to the liquid absorbed, and other technologies that use the same frequency span could hinder the process of obtaining information from an RFID tag (Zelbst & Sower, 2016). When it comes to GPS, it does normally not work indoors or in environments that have tall buildings, as they can block the system's line of sight access to satellites (Zelbst & Sower, 2016; Hunt et al., 2006). The tall buildings can sometimes reflect satellite signals that lead to inaccurate positioning (Zelbst & Sower, 2016). However, there are GPS systems that can be used indoor (Li, 2019). The signal from the GPS is amplified and retransmitted with the help of a repeater that sends a signal to the indoor users (Li, 2019). In a facility there can be many repeaters connected to an outdoor antenna or they can be placed in an open environment so that they can access the satellites (Li, 2019).

Shadowing

Another issue that is important to take into consideration is the tag placement, and especially when items are stored or stacked densely (Zelbst & Sower, 2016). Zelbst and Sower (2016) call this issue shadowing. Shadowing can occur when several RFID tags are stacked on top of each other, which can lead to that a passive RFID tag is not activated due to that the antenna from the reader is not able to power up all the tags. The tags stacked on top are in that case shadowing tags.

Accuracy

Kapoor et al. (2009) discuss that a 100% read rate is difficult to guarantee due to the dynamic nature of the reading process of RFID tags and the conditions around them. An RFID tag can display different scenarios, such as *true positive, true negative, false positive,* or *false negative. True positive* and *true negative* refers to when the RFID reader confirms that the tag is present/absent when the tag is actually present/absent. *False positive* refers to when the reader confirms that the tag is present when the tag is not. *False negative* then refers to when the reader confirms that the tag is absent when the tag is actually present. These different scenarios can have its consequences. For example, too many false positives can lead to stock-outs, which can result in a loss in revenue and customer satisfaction. Too many false negatives can, on the other hand, result in excessive inventory, which can cause obsolescence of inventory.

Information sharing

According to Pålsson (2018), the requirements for having a successful information sharing are identification technologies (e.g. barcode and RFID tag) that are linked in an electronic data interchange (EDI). Though in order to utilise the track and trace information the data has to be processed, analysed and actions have to be made from the company using the track and trace technology, otherwise, the data will not contribute to the improvement of the supply chain (Pålsson, 2018).

When there is a lack of conformity between different partners in the supply chain, it is usually due to insufficient information flow among the different partners who are involved in the packaging flow (Chan et al., 2006). Lack of information can cause handling of incorrect goods, incorrect handling can lead to product damage, and reclamation of packaging that can all result in great costs (Chan et al., 2006). Chan et al. (2006) mention that in order to minimise the likelihood of that to happen, the labelling should provide as much information as possible, e.g. specification of the material inside the packaging, handling precaution if there is some, stacking height and weight and the temperature for storing.

A summary of the challenges is presented in Table 4 below. The green colour symbolises what challenges there are with different technologies. For example, both technologies apply to different standards and laws all over the world. The red colour in the table symbolises the

challenges that the technologies do not have, such as GPS trackers do not have the same problem with shadowing as RFID tags. The yellow colour means that the challenge may occur with the technology. The challenge can be reduced, but it will require more resources, for example, to get a GPS tracker to work as good as an RFID tag inside facilities.

Table 4. Challenges with RFID tag and GPS tracker gathered from literature.

Challenges		
	RFID	GPS
Different standards and laws		
Bouncing signals		
Indoors		
Outdoors		
Shadowing		

4. Empirical data and analysis

This chapter presents the empirical data that was collected during the research process together with the analysis. The analysis compares the findings from the empirical data with the literature review. First, a brief description of the OEM's packaging flow together with analysis of the flow are presented in order to give the reader an overall understanding of the OEM's packaging flow and which actors are involved. Secondly, the packaging flow at each actor in the packaging flow is described in more detail, followed by empirical data collected from interviews that were performed both with internal employees and employees from different stakeholders together with analysis of each flow. Lastly, analysis of the whole packaging flow is presented. The sub-chapters have been divided into different areas where the researchers saw possibilities that RFID and GPS could be beneficial for the packaging flow. However, not all sub-chapters are analysed in the same areas due to the different areas were not applicable to all actors in the packaging flow. Examples of areas used in the sub-chapters are Scanning of packaging, Location, Human errors.

4.1 OEM's packaging types

The main types of packaging that are used are wooden pallets and smaller boxes made of plastic, and as mentioned before these packaging is called standard packaging at the OEM. Both of them come in different sizes to be able to fit different types of material required to build the end product. These two different types of packaging are so-called returnable, meaning that the packaging is circulating in the supply chain. The other type of packaging used by the OEM is called special packaging, which is also a returnable packaging. It is developed and used for specific parts or part families when standard packaging is not suitable. Moreover, it can have many different shapes. One type of special packaging is metal racks, which carry critical parts for the OEM. The special packaging flow has been included in this research together with the standard packaging as the flow differs from the standard packaging flow, especially within the OEM's plants.

4.2 Description of the OEM's packaging flow

After the packaging has been used within the plants, it is sent to the packaging terminal that stores the packaging until the OEM's material suppliers need them. The OEM puts a requirement that the material coming from their material suppliers have to be transported in a standard or special packaging to the OEM, depending on the type of the material. Therefore, the material suppliers always need to have enough packaging at their facilities to be able to send the material to the OEM. If the material supplier does not have the packaging in-house that is needed for the material to be sent to the OEM, the supplier needs to order packaging from the OEM. The

supplier orders packaging from the OEM through an IT system. After the order has been received in the IT system, the system notifies if the closest terminal has the required packaging in store or not. If the packaging terminal has the packaging in stock, the order is placed at the packaging terminal. Otherwise, the order goes to another terminal that has the required packaging available. A cross-dock terminal consolidates various shipments from different material suppliers, both from Sweden and abroad, into one shipment that transports the material to the OEM. The packaging terminal is driven by a company providing logistics services for manufacturing companies and the OEM buys its services where the packaging terminal stores and repairs empty packaging. Next to the packaging terminal is a cross-dock terminal, used for cross-docking material to the OEM's plants located all over the world. The cross-dock terminal is driven by the same company as the packaging terminal. Figure 2 shows how the OEM's packaging flow that was analysed travels through the supply chain. The packaging flow within each different facility will be described in more detail below.

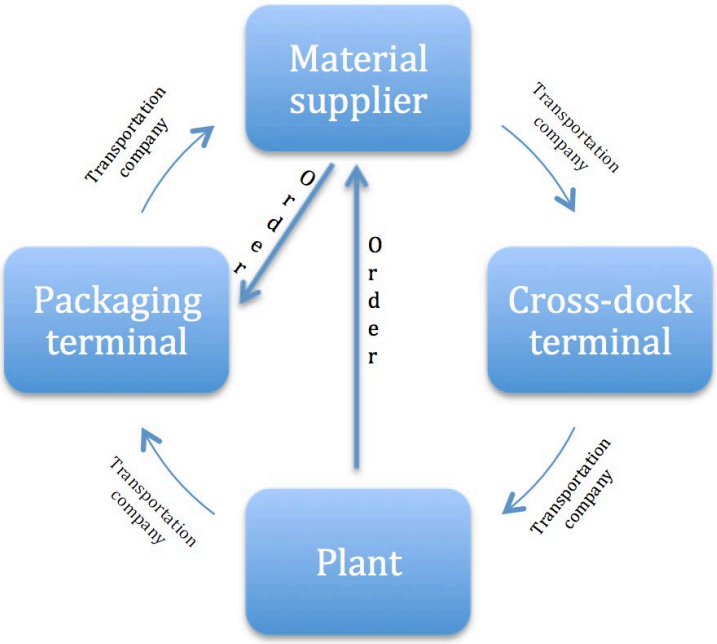

Figure 2. *OEM's packaging flow within the supply chain.*

The packaging flow in two of OEM's plants located in Sweden was studied in this research. These plants will hereafter be named plant 1 and plant 2. Plant 1 produces components for their customers all over the world, as well as components that are used in the end product, which is produced in plant 2. The three different packaging types were tracked and the flows for each type were later mapped.

4.3 The Packaging Terminal

This subchapter starts with explaining the packaging flow at the Packaging Terminal. Furthermore, the findings of the interviews and site visits are analysed together with the literature.

4.3.1 Empty packaging flow at the Packaging Terminal

When the empty packaging arrives at the packaging terminal, it is evaluated in a quality inspection if it is in good condition to be used again. If the condition of the pallet is not good enough to be used again it is repaired if possible, otherwise, it is scrapped. All boxes are washed before being stored at the packaging terminal and transported to the supplier, especially if they are unclean according to the OEM's standard and also to remove old labels from the boxes. In that case, they are transferred to a washing area after they arrive at the packaging terminal to be cleaned. There, they go with a conveyor belt through an automatic washing machine where they are both cleaned and dried. After having gone through the washing machine, the boxes are transferred to the storage area. When it comes to the pallets, they are placed on a conveyor belt at the receiving area and transported to the sorting area. At this area, the pallets are inspected if they have been damaged or not during usage and then automatically taken apart. After they have been broken down into individual pieces, i.e. pallets, frames, lids and spacers, they are transferred to the storage area until the supplier needs them. At the packaging terminal, all packaging is stacked on top of each other. Boxes are stacked on top of each other, upside down on a pallet. The frames are bundled together, the same goes for the lids and the pallets. Concerning the special packaging flow, it is not stored or handled at the packaging terminal. This is because one special packaging is much more expensive than a standard packaging, leading to that the amount of special packaging is just enough to cover the time it takes for the packaging from the supplier to the plant and back to the supplier. See Figure 3 and 4 for the packaging flow of boxes and pallets at the packaging terminal.

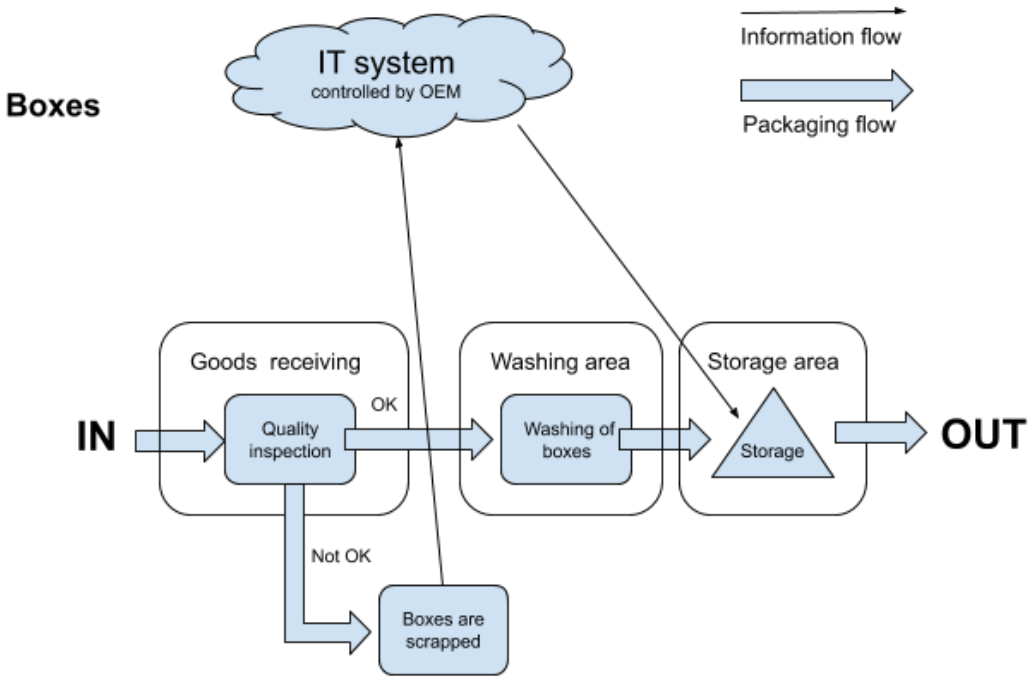

Figure 3. *The packaging and information flow of the boxes at the packaging terminal.*

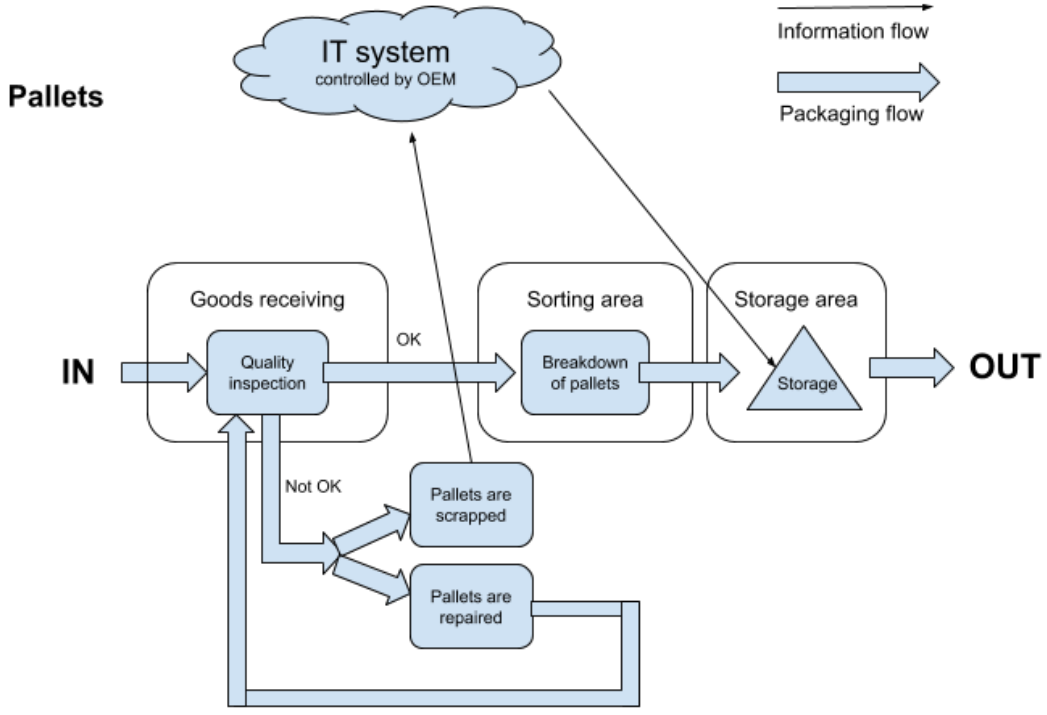

Figure 4. *The packaging and information flow of pallets at the packaging terminal.*

4.3.2 Analysis of RFID tags and GPS trackers at the Packaging Terminal

Scanning of packaging

When the packaging is stored at the packaging terminal it is never scanned. This due to the fact that there is nothing attached to the packaging that can be scanned, such as a label or RFID tag, when the packaging is empty. This results in the packaging terminal and the OEM do not know exactly how much packaging is located at the packaging terminal. Since neither the pallets nor boxes are scanned at the packaging terminal, the use of RFID tags would not bring any value in relation to reducing the manual scanning of the packaging. By having many packaging with RFID tags attached to it stored in the same area, the risk for tag shadowing is higher (Zelbst & Sower, 2016). At the packaging terminal, all the packaging is stacked on top of each other. If an RFID tag would be attached to a pallet or a box it has to be strong enough so that all tags could be read at the same time. This due to what Zelbst and Sower (2016) mentioned, an RFID tag needs to be placed on a good location so that it can be read but also so that the risk for shadowing is low. However, there are tags that operate well when items with the tags are stacked (Zelbst & Sower, 2016). In order to know which tag to choose, the OEM has to understand the environments that the packaging and tag are exposed in, otherwise, the tracking of the packaging will not be optimal (Zelbst & Sower, 2016).

Location

As mentioned before, it can be difficult to locate the packaging. The area where the packaging is maintained and stored is big and this makes it harder to know how much packaging is being maintained, how much is waiting to be sorted and how much is waiting to be shipped. A GPS tracker would provide this kind of information (Roos et al., 2005), however, according to the Process Development manager the need for the packaging's location and real-time update at the packaging terminal is considered unnecessary. This due to the packaging can stand at the packaging terminal for several days and having a GPS tracker on a packaging standing still for such a long time would be too expensive and not bringing any value. From the packaging terminal and OEM's perspective, it would be sufficient to know when the packaging has entered the packaging terminal and when it leaves. In that case, an RFID tag would be a better solution than a GPS tracker. An RFID tag can provide more information than a GPS tracker. A GPS tracker gives information about a location, while RFID tag has the ability to store information about the packaging, such as where it has been, what it is, and what it contains (Misra & Enge, 2006; Zelbst & Sower, 2016). Depending on what the OEM requests to know about the packaging at the packaging terminal, it will affect the choice of a technical device. If the only information is how much packaging is at the packaging terminal, then there is no need of having a device that can handle more information than asked for.

Human error

When a truck is loaded with packaging to be sent to the material supplier there is no guarantee that the trailer has been loaded with the correct packaging or in the correct amount. The result of this can be that the level of packaging in the IT system does not match with the reality on the packaging terminal. This can later contribute to that the levels in the IT system does not match how much and what type of packaging has arrived at the material supplier in reality. Furthermore, if there were some sort of track and trace technology, the transportation cost could be reduced (Lam & Ip, 2019) due to the fact that the employee at the packaging terminal would know what he or she is loading on the trailer. This would then result in the need for sending back the trailer with wrong packaging from the supplier would not be needed and increase the customer service as mentioned by Lam and Ip (2019).

Inventory

The Strategic Packaging Planner and the Price Manager at the OEM said that it could be beneficial to have RFID tags and GPS trackers on the packaging. Especially when it comes to knowing how much packaging is available at the packaging terminal and if there is a need for buying new packaging in order to manage the demand from suppliers and plants. Furthermore, during the site visit at the packaging terminal, it was explained that the packaging terminal did not track how much packaging was going in or out of the packaging terminal. This due to the fact that the OEM did not require the packaging terminal to know the exact amount of packaging located at the packaging terminal, only when a shipment with what type of packaging, the amount and to whom it had been sent from the packaging terminal. If RFID tag would be attached to the packaging, which would be read when the packaging would arrive to and departure from the packaging terminal, the real amount of packaging located at the packaging terminal would be known, which would help with the decision making of how much packaging would actually be needed to invest in as Hunt et al. (2006) mentioned. In addition, with improved decision making regarding how much to invest in packaging, it would result in less obsolescence (Zelbst & Sower, 2016).

Environmental aspects

The boxes used by the OEM are cleaned when they arrive at the packaging terminal. All boxes then enter the big washing machine and are cleaned with high-pressure warm water and later dried in a warm dryer. This results in that if the boxes would have an RFID tag or a GPS tracker, the risk of the tag or GPS falling off the packaging has to be low. For the pallets stored at the packaging terminal, there is another obstacle by having RFID tags on them. Since more or less all pallets are stored outside, it contributes to that the pallets are exposed to all different kinds of weather. A pallet of wood becomes moist when it is raining, snowing or if the humidity is high. According to Zelbst & Sower (2016), when a pallet with an RFID tag absorbs humidity it can be difficult to read the information on the tag due to the moist.

4.4 Material Supplier 1 and Supplier 2

This subchapter starts with a description of the packaging flow inside supplier 1's facilities. It continues with findings from the interviews performed during the site visit at supplier 1 and from the questionnaire that was sent to supplier 2. At the end of this subchapter, the findings are analysed together with the literature.

4.4.1 Packaging flow at Supplier 1

The empty packaging arrives at the Supplier 1 from the packaging terminal by truck. Each delivery with packaging has a delivery note stating what type of packaging is in the trailer and the amount of the packaging. The forklift driver, that unloads the trailer, make sure that the correct type and amount of packaging are within the delivery by counting the packaging and comparing the amount with the delivery note that was delivered. Since the packaging does not have any identification, the forklift driver needs to know the different packaging types in order to be able to notice if something is incorrect or not.

If the delivery is wrong, i.e. it does not include the correct type and amount of packaging, the Supplier 1 makes a claim to the OEM. If the wrong packaging has been sent to the Supplier 1, the Supplier 1 sends the packaging back to the packaging terminal. If too little packaging has been sent, the packaging terminal sends more packaging to the Supplier 1. However, if the delivery to the Supplier 1 is correct, the packaging is stored at the Supplier 1's yard until it is needed in their production.

The Supplier 1 stores all material in their own packaging in-house until the OEM plants order the material. The reason for not using the OEM's packaging at the beginning of the production at the Supplier 1's side is because the Supplier 1 has to pay rent for the OEM's packaging during the time the packaging is located in their facilities. This, therefore, reduces the cost for the Supplier 1 due to the fact that the packaging is fewer days at the Supplier 1's facilities.

The material, that is stored in an automatic warehouse, is ordered from the automatic warehouse when it will be packed in the OEM´s packaging. The Supplier 1 has a label on their packaging that is scanned before the parts are repacked in the OEM's packaging. The OEM's packaging is given a new label, according to an agreement between the OEM and the material Supplier 1, when the repackaging is done. This, since the OEM requires the suppliers to have certain labels according to the OEM standards. The packaging is then scanned automatically and is transported with the conveyor belt to the outside of the Supplier 1's plant. A forklift driver comes and picks up the packaging and stores it in the yard until a truck arrives. See Figure 5 for the packaging flow of packaging at Supplier 1.

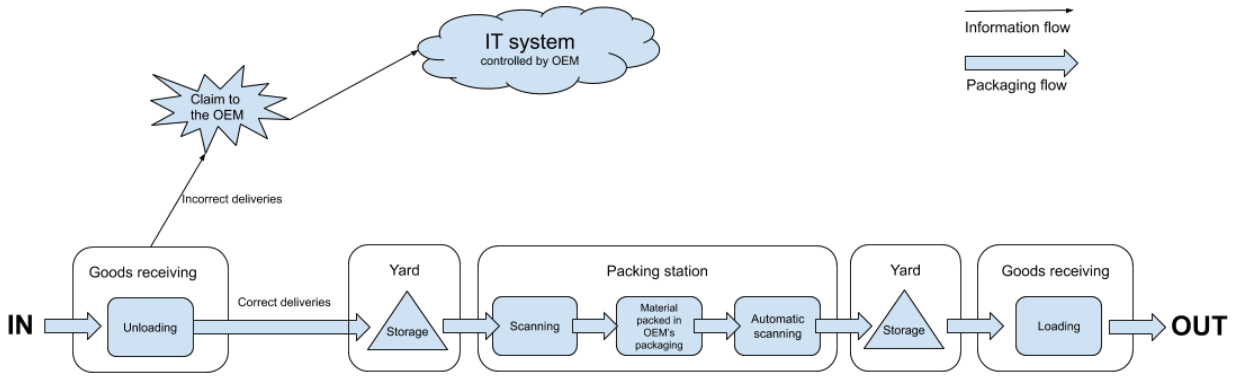

Figure 5. *The packaging and information flow at Supplier 1.*

4.4.2 Analysis of RFID tags and GPS trackers at the material suppliers

Scanning of packaging

Since both Supplier 1 and 2 only scan the packaging before it leaves their facilities to be transported to the OEM plants, the manual scanning of the packaging is only performed one time at each supplier. The manual scanning of the packaging at Supplier 1 is done before the material is loaded from the supplier's packaging into the OEM's empty packaging, and RFID tag could reduce that manual scanning. However, the manual scanning applies to Supplier 1's packaging and is not applicable to OEM's packaging. As for the packaging terminal, the risk of tag shadowing also applies to the supplier's facilities due to several packaging stacked together and on top of each other (Zelbst & Sower, 2016). The same concern, therefore, applies to the RFID tags being placed on a good location at the packaging in order to be read and reducing the risk of tag shadowing. Regarding the tracking of the packaging within the suppliers' facilities, it is difficult to get a signal and track the packaging when it is located inside if using a GPS tracker (Zelbst & Sower, 2016).

Human error

One example that Supplier 1 brought up was that it happened that the packaging terminal sent the wrong packaging to the supplier. The consequences of this were that the levels in the IT system did not match the reality. The packaging terminal could, for example, have a lower amount of one size of a pallet and the OEM's IT system would then show a higher amount of pallet but low on another sized pallet. Furthermore, this results in that the OEM's IT system would not match the physical level at the supplier. If the supplier would not notice this when the truck loaded with packaging would arrive, the levels would still be wrong and in the end the supplier has to pay the cost for not having the right amount of packaging compared to the system, i.e. if there is an inventory stock out or having excessive inventory at the storage area. The only way for the

supplier to notice if the packaging was right or wrong was if the employee at the supplier would know the different types of packaging. The supplier did not have any way of checking the packaging, they trust the packaging terminal to load the right type of packaging. In addition, since there is no scanning of the packaging when leaving the packaging terminal, it is difficult to know if it is the correct packaging or not. Another example of a shipment with the wrong packaging is when the supplier sends the material in the wrong packaging to the customer. As for the packaging terminal, the supplier would usually not realise that the wrong packaging had been sent until it had arrived at the customer. If there would be an RFID tag attached to the packaging, this could be verified fast and the time to react on the mistake would be shorter (Kong & Yu, 2018), or the problem could even be eliminated with the technology. The RFID tag could then make a signal when leaving the supplier's facilities that the wrong packaging has been loaded according to the Innovation Manager at the OEM.

Location

All of the OEM's packaging is stored at the yard at the Supplier 1. The packaging can both be stored inside tents and outside under a roof. Furthermore, both Supplier 1 and 2 have other customers as well that have their own packaging. Due to this, the suppliers have a lot of different packaging at their facilities. Supplier 1 was positive of the idea of having an RFID tag or a GPS tracker attached to the packaging owned by the OEM. This would help the supplier to locate the packaging in the yard. However, according to the response from Supplier 2, they did not see that implementing the track and trace technologies to the OEM's packaging would be more valuable for their in-house processes. Véronneau and Roy (2009) discussed that one of the advantages with the track and trace technology is the ability to know the location of an item. By knowing the packaging's location at the supplier's facilities with the help of GPS trackers, it could reduce the time of finding the packaging, especially when the supplier has a great amount of different packaging, both the OEM's and other customer's packaging. Moreover, to have an RFID tag or a GPS tracker on the packaging would help the supplier to know what type of packaging they have received or not. As mentioned before, it can happen that the packaging terminal sends the wrong packaging to the supplier. In that case, when the OEM asks the supplier why the level of the packaging that was wrongly sent is higher than it is supposed to be, the supplier can control it easier with the help of the technologies. The technologies may even contribute to that the OEM does not need to check with the suppliers and their levels of packaging if it was easier to track and trace the packaging. This could, in the long run, result in fewer man-hours are spent on controlling the inventory levels of packaging, both from a supplier and OEM's perspective.

Inventory

Supplier 1 thought that the biggest benefit they would have from an RFID tag or a GPS tracker on the packaging would be to have better control over the packaging inventory levels. As mentioned before, when the packaging is delivered to the supplier, the IT system at the OEM updates the inventory levels but the supplier does not have a system to validate that the packaging that was sent from the packaging terminal is the same as the OEM's IT system says.

Supplier 1 mentioned that the inventory levels at the supplier were compared to OEM's IT system around four times per year. If the inventory levels do not match with the IT system, the supplier has to search for the missing packaging and if they cannot find it, the supplier has to pay a fee for it.

Supplier 1 also mentioned that to begin with, the tracking of the racks would be most beneficial for them. This due to that the fee for a missing rack is a lot higher than the fee for a pallet or a box. Furthermore, supplier 1 explained that for the more expensive packaging such as racks, the time they were allowed to have it at their facilities before starting to pay the rental cost of the packaging was shorter compared to the pallets and boxes. As the pallets and boxes could be stored for 21 days at their facilities without having to pay the rental cost, the number of days wes around ten days less for the special packaging. When that time runs out, the supplier has to pay for every day the packaging is at their facilities. Track and trace of the packaging would help the supplier to know how long time the packaging has been at their storage, when to order new packaging and how often they have to pay extra for the packaging due to that it has been at their storage longer than needed. In addition, by knowing the quantity of each type of packaging they have at their storage, it would help them with knowing the correct amount of packaging to order from the OEM each time.

As mentioned before, one of the benefits of using RFID tags and GPS trackers is knowing the exact amount of packaging in stock. Supplier 1 mentioned that keeping the OEM's packaging in stock leads to a high inventory cost due to the rent of packaging. As they do not know the correct amount that they have at their facilities each time, it is impossible for them to know the exact amount of packaging that they need in order to have enough packaging. They have to order more to have safety stock due to a long-time interval between the ordering time and the arrival time of the packaging, which is 2 weeks. That leads to even higher inventory cost compared to what is actually needed. Zelbst and Sower (2016) mentioned that RFID tags could improve asset visibility and thereby better decision-making capabilities. For the suppliers an RFID tag can result in that they know when to order new packaging and can keep the inventory cost low. Additionally, better information sharing leads to better allocation of inventories and reduces the bullwhip effect (Ouyang, 2007). Considering the different information that the RFID tags and GPS trackers can provide, i.e. the RFID tag providing discrete information of the packaging at specific locations and the GPS providing real-time information about the packaging (Lam & Ip, 2019), it was not considered necessary for the supplier to know the real-time information of the packaging all the time. The discrete information of the packaging can be obtained solely with the RFID tags. As their biggest concern is the cost that follows with renting the OEM's packaging, their biggest benefit would be to lower the rental cost.

In general, Supplier 1 was really interested in the implementation of RFID tags and GPS trackers to the OEM's packaging, while Supplier 2 did not see any benefits of implementing the technologies to their operation. Supplier 1 discussed that if the handling of the packaging would

be the same as it currently is then it would be beneficial for them to implement the track and trace technologies to the packaging flow. Then, they could notice the deviations when the packaging disappears earlier and when they send wrong packaging to their customers.

4.5 The cross-dock terminal

The packaging flow at the cross-dock terminal is described in this subchapter together with findings from the interview performed during the visit. The findings and literature are then analysed at the end of this subchapter.

4.5.1 Packaging flow at the cross-dock terminal

The packaging with material arrives at the cross-dock terminal from various suppliers by trucks. When a truck arrives, the driver has to announce in the reception that he or she has arrived but also what their assignment is at the cross-dock terminal. The driver has documents that have to be shown in the reception. This is because the administration has to make sure that the documents are correct and to know where to send the driver to load or unload the material. When the documents are according to standard, the truck driver is allowed to enter the area and given a place at the cross-dock terminal to load or unload the material.

If the truck driver will unload material at the cross-dock terminal, he or she will be given a place at the inbound area for the incoming material. It is then the truck driver's job to prepare the truck by opening the trailer so that it can be unloaded. The truck driver then has to wait for a forklift to unload the material. In order for the forklift drivers to know what the next assignment is, they get an update in their computers inside the forklift that is sent by the administration. When all the packaging has been unloaded, it is counted in order to know if there is a complete shipment or not, meaning if all the packaging has arrived from the supplier. The IT system is then updated with how much packaging has arrived. When all the packaging has been counted and the IT system is updated, a new shipment label, containing the address of where each shipment should be transported and how many packaging is part of the shipment, is put on the packaging. When all shipments have received a new label, the packaging is sent to the outbound area in the cross-dock terminal. All the packaging is placed in the correct place at the outbound area based on the destination each shipment has.

In the area for goods leaving the cross-dock terminal, the trucks can come empty from another destination. It can also be that they have unloaded material or empty packaging at the cross-dock terminal and then driven through the cross-dock terminal to the outbound area. When the truck arrives, it is loaded with all shipments going to one destination. The forklift drivers scan the shipment labels at the time they load all the packaging on the truck. Before the truck can leave the cross-dock terminal, the administration has to make new documents for the truck. The

documents contain for example what the truck is loaded with and the destination of the material. When all documents have been made, the truck is allowed to depart from the cross-dock terminal. See Figure 6 for the packaging flow at the cross-dock terminal.

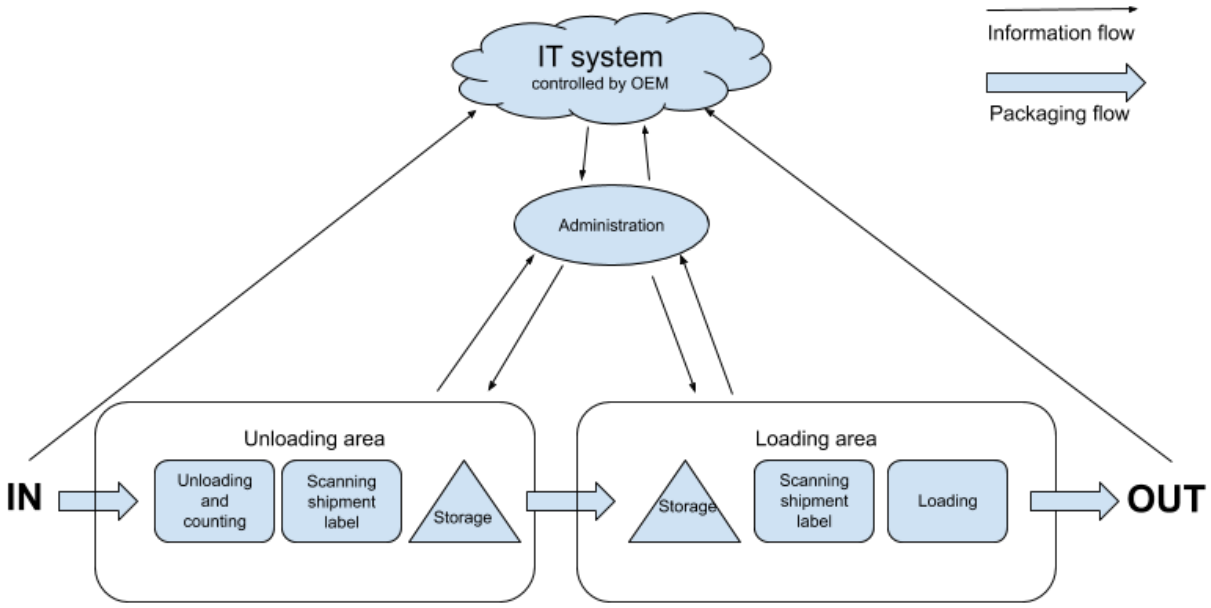

Figure 6. *The packaging and information flow at the cross-dock terminal.*

4.5.2 Analysis of RFID tags and GPS trackers at the cross-dock terminal

Scanning of packaging

From a cross-dock terminal perspective, the employees at the cross-dock terminal have had problems with too much manual scanning. In order to reduce the number of scanning, the cross-dock terminal chooses to handle all packaging on a shipment level. One shipment can include a number of packaging. The shipment level contributes to that the employees at the cross-dock terminal only have to scan each shipment instead of each packaging. However, the employees still have to make sure how much of each shipment has arrived in order to transport the amount of packaging to the right location at the cross-dock terminal. The employees then have to count each packaging and compare the counted number with what the OEM required in the booking. If the two numbers do not match, the information is reported to the OEM. By having an RFID tag on the packaging, it would result in that the packaging could be scanned automatically when passing through an RFID reader. The amount of packaging that would be scanned could then be presented to an employee at the cross-dock terminal and he or she could compare if the number

of RFID tags matches the number in the shipment. This would result in a reduction of handling time, man-hours, and human errors when making wrong counting on the packaging. The reduction of man hours can then lead to that the waiting time to load and unload the trailers will be shorter as well. When several RFID tags are automatically scanned at the same time, there is a risk of tag shadowing as Zelbst and Sower (2016) mentioned. This needs to be taken into consideration when there is an amount of packaging involved at the cross-dock terminal.

Location

From the processes view, there are different processes depending on if it concerns the packaging or the material within the packaging. It can happen that the packaging is missing or that the material is packed in the wrong packaging. Another thing that can happen is that the material or some of the material gets lost on the way to the cross-dock terminal. Based on this, the Process Manager at the OEM thinks that it can be beneficial to have RFID tags and GPS trackers on the packaging. Thus, it will show where the packaging was before it disappeared, such as if it has entered the cross-dock terminal or if it has been sent out to the plant. This is in line with what Gnimpieba et al. (2015) mentioned about knowing where the packaging has been in case it gets lost.

Labels

When the packaging has been unloaded at the cross-dock terminal and all the packaging has been counted, the employee prints a new label for the shipment due to that the labels on the packaging are not always containing the information that the cross-dock terminal needs. This has resulted in that the employee at the cross-dock terminal prints one new label for each shipment containing information such as the destination of the shipment and how many packaging the shipment contains. The reasons behind the shipment label are, as explained above, to reduce the number of scanning but also to give the right information to the employees at the cross-dock terminal. Since the employees at the cross-dock terminal are printing a new label for each shipment that is only scanned at the cross-dock terminal the result is that there are many labels only scanned one time and then removed. By having RFID tag on the packaging, the extra label for the cross-dock terminal would not be needed since Véronneau and Roy (2009) state that the RFID tag can be used instead of a label. At the cross-dock terminal there were 300.000 shipments handled in the year 2018 meaning that by having RFID tags on the packaging, that number of labels could be reduced. In addition, the cross-dock terminal would then be more sustainable.

Information sharing

From the visit to the cross-dock terminal, information sharing was brought up. The Development manager thought that RFID tag and GPS tracker could be beneficial in the process, however, the technology would work better if the information sharing was more efficient. As for now, the information about when a truck with material arrives and what material it is carrying is not given to the cross-dock terminal. This sometimes results in that some days too many trucks arrive at the same time at the cross-dock terminal and exceed its capacity. When this happens, the trucks

have to wait outside the cross-dock terminal and wait for its turn. It happens that the plants are in need of a material that is loaded in a truck that is waiting outside the cross-dock terminal. If the information about when a truck would arrive and what it is carrying would be available, the employees at the cross-dock terminal could plan for the arrival. By knowing the details of the shipment in each truck, the employees could estimate the time for unloading the truck depending on how much is inside each shipment. It could also contribute to that they could ask the plants which truck has the highest priority if there would be many trucks arriving at the same time. The result of having a good information sharing would not only contribute to better planning of which truck to unload and load, but also help the employees at the cross-dock terminal to act fast on deviations such as a truck arriving unannounced to the cross-dock terminal (Zelbst et al., 2010). It happens that there is unannounced transportation arriving at the cross-dock terminal, or more transportation than expected. This results in that there are more shipments to one customer than planned for. In that case, the cross-dock terminal orders extra transportation or the shipment waits until another transportation is going to the same location as the shipment. If the information on when a truck will arrive would be accessible with a GPS tracker, the cross-dock terminal could plan better and notice if an unannounced truck is on the way to the cross-dock terminal. Furthermore, if the information could be shared to the plants it could also help them make sure that the assembly would not be affected by delays, according to the Process Manager at the OEM.

Since the cross-dock terminal is only looking at the shipment level and not on packaging level, the Development Manager at the cross-dock terminal could not see any high benefits for the cross-dock terminal to have an RFID tag or GPS tracker on each packaging, at the moment. However, it can be beneficial in the future but he thinks it is more important to start by improving the technology existing at the time and the information sharing within the packaging flow. Furthermore, the company owning the packaging terminal and cross-dock terminal uses GPS trackers on all truck trailers they own. Since they can track the trailers and know what is inside the trailer, this information could be shared to the OEM as well if the information sharing was more transparent. From the Development Manager's point of view, it was more important to focus on what was used at the time and the information sharing than the technology itself. This since track and trace could be performed with the labels and transparent information sharing in the same way as RFID tags and GPS trackers. A suggestion that was brought up from the Development Manager was to increase the usage of the existing assets. One example was the labels that the suppliers print and add on the packaging. The labels are not always carrying the right information and sometimes it is a label that the suppliers use but it is not the labels the OEM requires. This can result in a shortage of information about the packaging and material but also increases the risk of misunderstanding at the cross-dock terminal. Pålsson (2018) mentioned that having a label or identification solution attached to the packaging is important in order to have information about the product within the packaging. If there could be some sort of assurance that the correct labels carrying the right information are used, the need of

implementing an RFID tag on the packaging may not be needed since the tag carries the same information as the label.

Concerning the racks that were looked into in this research, it is more critical to have a GPS tracker attached to it since the rack is carrying a component that can be very critical for the OEM plant if it gets lost on the way to the plant. A rack can clearly have an RFID tag attached instead of a GPS tracker, however, if the OEM requires to know the real-time location then a GPS tracker might be a better solution (Misra & Enge, 2006).

Human error
Since the labels on each packaging are not scanned but instead the packaging is counted, the risk of counting wrong is high. The outcome of this would be that the plant would receive wrong information on what has arrived at the cross-dock terminal since the cross-dock terminal has to give the information to the plants. Furthermore, it will also affect the suppliers due to that it will show in the system that their delivery performance is not as good as the OEM may ask for and this can lead to consequences for the suppliers such as they will be given a fee.

4.6 Plant 1 and Plant 2

This subchapter starts with explaining the packaging flow through plant 1 and plant 2. It continues with findings from interviews performed during the visit and from additional questionnaires that were sent out after the site visits.

4.6.1 Packaging flow of pallets in Plant 1

Incoming material arrives in a pallet to the goods receiving area at the plant by truck. The pallet carrying the material is placed on a conveyor that transports the pallet to a scanning station. When the pallet arrives at the scanning station, both the pallet and the label that is attached to the pallet are scanned by an automatic scanner. This is to make sure that the pallet is an OEM's standard packaging, in a good condition, and to know what material is inside the pallet. After the pallet has gone through the scanning station, it travels with a conveyor to a storage. If the pallet does not fit the requirements of these automatic processes, for example, if it is too big or weights too much, the information from the automatic scanner will indicate that the pallet needs to be changed. There could also be some bigger damage to the pallet, or the material could be loaded in a type of pallet that does not fit the OEM's standard packaging requirements, such as a Euro pallet. In these cases, the pallet will be sent to a station nearby to be repacked or downsized.

Repacking is done when the material is packed in damaged packaging. The employee then unloads the material from the damaged packaging and loads it in new packaging. Then the material is loaded in an OEM's standard packaging, but it could also be divided into a number of

packaging due to a large amount of material inside a pallet, leading to a too heavy pallet. That process is called downsizing. After the pallet has gone through the repacking or downsizing station, it is transported back to the scanning station at the goods receiving. If it is approved, it is transported to the storage.

Occasionally it happens that the packaging carrying the material does not have the OEM's standard label. It can depend on if the supplier did not have the right type of label from the beginning or can also be that the label has fallen off during transportation. The packaging is then sent to another station and the employees print new labels and attach them on the packaging. When the packaging has the right label, it is sent to the storage.

The storages are based on how often the parts are used. There are three different storages divided into low, medium and high runners. Low runners are stored in an automatic warehouse. When a part is needed at the kitting station, the automatic warehouse and an employee working next to the warehouse get information that it is time to refill material at the kitting station through an MRP system when scanning of empty packaging at the kitting station is done. The warehouse brings the part to the employee outside the warehouse. The employee gets a packing instruction from the MRP system about which part should be packed, in what type of packaging and in what amount. Afterward, it is transported to the kitting station with a forklift. Before being transported to the kitting station it is scanned, but also when it is placed in the material facade at the kitting station. The medium and high runners are stored in manual storage until they are needed at the kitting station. At the kitting station, which is the endpoint for most of the pallets before departing the plant, the materials are prepared in smaller kits to be assembled at the assembly line. When a pallet at the kitting station and in some cases the assembly line is empty, it is scanned and picked up by a forklift. The forklift then transports it back to the goods receiving area. When a truck has been loaded with pallets at the goods receiving area, it is transported to a packaging terminal, where the packaging is disassembled to be reused. The activities in the packaging flow of the pallets are presented in Figure 7.

4.6.2 Packaging flow of boxes in Plant 1

The flow for the plastic boxes is similar to the flow of the wooden pallets but there are some differences. When a truck with boxes arrives at the plant, the boxes are transported to the goods receiving area where they are scanned at the scanning station and then transported into the storage. All plastic boxes are stored in an automatic warehouse when they arrive at the plant. The materials stored in plastic boxes are divided into low, medium and high runners. The low runners are kept in the automatic warehouse until the material is needed at the kitting station. The medium and high runners are sent to the supermarket to be stored until they are needed at the kitting station.

When a material is needed at the kitting station, a tugger train will pick it up from the storage and transport it to the kitting station. At the kitting station, the material is combined with other

materials to make smaller kits and send to the assembly line. When the box is empty, it is scanned and picked up by a tugger train. The empty box is later transported back to the goods receiving area to be packed on a truck and sent to a packaging terminal to be cleaned and then reused. The activities in the packaging flow of the boxes are presented in Figure 7.

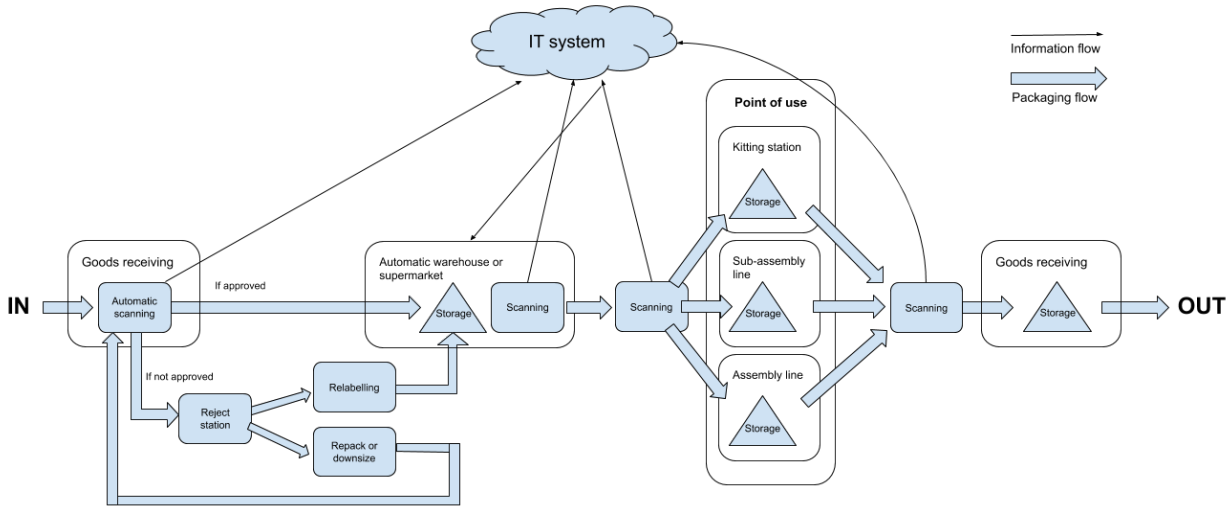

Figure 7. *The overall flow of pallets and boxes within plant 1 and 2.*

4.6.3 Packaging flow of racks in Plant 1

The special packaging that has been analysed in plant 1 are racks that are placed under finished components that are produced in plant 1. The racks are used for transporting the components to plant 2 where the components are a part of the final product produced in plant 2.

When the empty racks arrive to plant 1, they are unloaded from the truck and placed in goods receiving area next to the unloading station. From there, a forklift picks them up and transports them to the end of the assembly line, where the finished components are removed from the assembly line and placed on the racks. The finished components are transported with an Automated Guided Vehicle (AGV) from the assembly line to the rack's location, where the components are placed on top of the racks with a robot. After the components have been put on the racks, they are transported with a forklift to a testing area, where a quality inspection of the component is done. After the quality inspection, the racks together with the components, are transported with a forklift to a paint shop where the painting of the components takes place. From there, the racks including the components go to a storage area, waiting to be loaded into a truck and transported to its destination. After the racks have arrived with the components at their

destinations and been used, they are sent back to plant 1. See Figure 8 for the packaging flow of racks in plant 1.

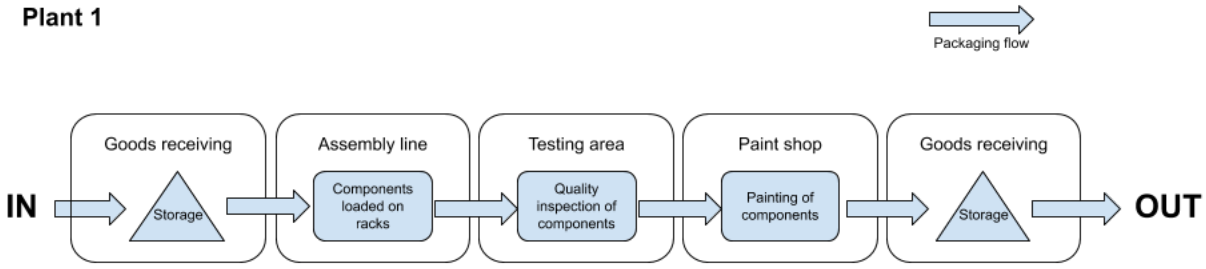

Figure 8. *The packaging flow of racks within plant 1.*

4.6.4 Packaging flow of pallets in Plant 2

At plant 2 the packed material arrives at the goods receiving area. All material is divided into two different categories; high and low runners. Low running material is stored in an automatic warehouse located close to the goods receiving area until they are needed at the point of use such as kitting station or assembly line. Most of the high runners are sent directly to the point of use or stored in a local warehouse close to the point of use. Close to the goods receiving area, there is an area for repacking, downsizing and relabelling of packaging for materials. This is because sometimes the material is packed in a packaging that cannot be handled in the automatic warehouse. The reasons for the need of repacking and downsizing are that the warehouse cannot handle damaged packaging and it only handles two sizes of the OEM's pallets.

When the material that is packed in pallets arrives at the goods receiving area, it is placed on a conveyor belt and scanned with an automatic scanner. The label is scanned in order to know what is inside the pallet. Furthermore, the pallet itself is scanned in order to see if it is in the right size, according to the OEM's standard packaging, or has been damaged on the way to the plant. If the pallet has the wrong size, needs to be repaired or requires a new label, it is sent to the area for repacking, downsizing and relabelling with an overhead conveyor. Otherwise, it is sent directly to the storage or point of use. When the pallet is empty at the point of use, it is manually scanned by the employee who is working at the point of use. This becomes a trigger to the forklift driver working in the plant that it is time to refill material. The empty pallets are collected and transported to a packaging terminal.

4.6.5 Packaging flow of boxes in Plant 2

All boxes containing material arrive in pallets at the goods receiving area, are automatically scanned, and then stored in an automatic warehouse for boxes. However, the boxes with materials can also be stored at the supermarket, which is a manual warehouse closer to the point of use compared to the automatic warehouse. There are mainly high runners that are stored in the supermarket, however medium and low runners can be stored there as well. The supermarket supplies material at the point of use. Empty boxes at the point of use are scanned by the tugger train driver. This is the trigger for the refill of material. When the material is needed from the automatic warehouse, it is automatically loaded on a rack with many shelves. When it is time for a refill at the point of use, a light on top of the rack will turn on so that the forklift driver knows that it can be sent to the point of use. All boxes are scanned again when they are placed in the correct position at the point of use. When the empty boxes are scanned, they are taken to an area where they are packed to be transported to the packaging terminal.

4.6.6 Packaging flow of racks in Plant 2

When the racks, which contain the component produced in plant 1, arrive at plant 2 they are transported with a forklift to a storage area where they wait until being used in the production at plant 2. When the components are needed in the production, a forklift picks up the racks including the components and transports them to the assembly line. After being used at the assembly line, the empty racks are transported with a forklift to the goods receiving area until they are transported with a truck back to plant 1. The packaging flow of racks in plant 2 can be seen in Figure 9.

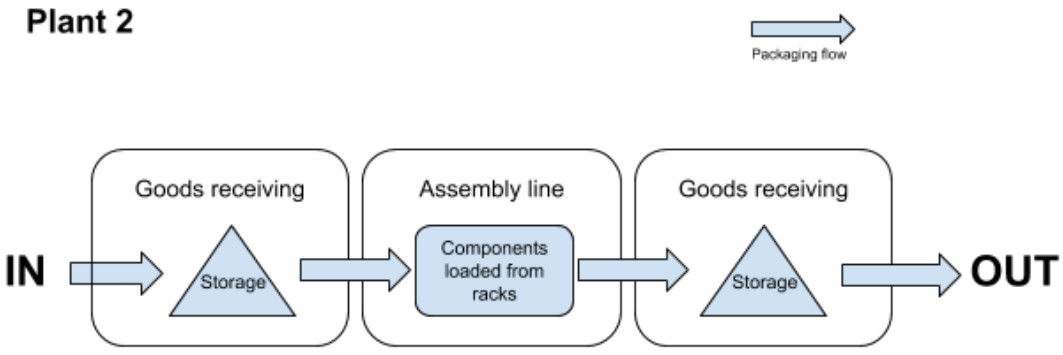

Figure 9. *The packaging flow of racks within plant 2.*

4.6.7 Analysis of RFID tags and GPS trackers at Plant 1 and 2.

Scanning of packaging

During the interviews, there were many of the interviewees at the OEM plant that mentioned that RFID tag could be helpful in the aspects of reducing the number of manual scanning of the packaging. The Internal Logistics Development Manager, Development Manager, and Process Manager Handle Material at Plant 1 said that there was a lot of manual scanning performed from the time the standard packaging with material arrived at the plant until the packaging was empty and left the facility. Furthermore, they mentioned that if the manual scanning could be reduced it could result in savings in handling time. The reduced handling time leads to reduced man-hours, which naturally lowers the labour cost. As Véronneau and Roy (2009) state, one of the main reasons for starting to use the RFID technology is moving from the ordinary barcode system to scanning through radio frequency. This can reduce the need for a human involvement but the same information is still obtained as with the ordinary barcode system (Zelbst et al., 2010). When looking at the packaging flow at both of the plants within the OEM, there are several barcode scanning locations where manual barcode scanning is performed. Manual scanning is performed before the standard packaging is transported to either the kitting station, supermarket, sub-assembly or assembly line, when it is placed in the material facade at these locations, and when it is empty at the same locations. An RFID tag could then reduce the manual scanning of all these occasions. However, when it comes to special packaging, there is no manual scanning of the packaging.

Environmental aspects

An RFID tag attached on the standard packaging can reduce the number of scanning inside the plants, however, the signal from the RFID tag has a tendency to bounce if there is a lot of metal around the tag (Zelbst & Sower, 2016). The metal parts can be in the shelves where the packaging is placed for storage and at the point of use. Additionally, if the packaging is stacked inside the plants this can lead to that it is harder to read the tags due to shadowing (Zelbst & Sower, 2016).

Zelbst and Sower (2016) stated that GPS trackers do normally not work indoors due to the building is blocking the signal to access satellites. If it would be an RFID tag attached to the packaging, it must be scanned in order to know where it is. With the RFID tag, the plants can see where the packaging was the last time it was scanned but not where it is at the moment during transportation. The Customer Success Manager at the Smart technology company mentioned that even though GPS trackers do often not work well indoors, there were some track and trace solutions that could be used within companies' facilities, but with the use of another network, such as GSM, LoRaWan or a SigFox network, instead of satellites.

Location

The location where packaging is located is a problem for the OEM. During the interviews, an example was brought up regarding where the material was stored in the yard at the plants. Often when the trucks arrive with the trailers, the truck leaves the trailers with material and the employees at the plants unload the trailers when there is space in the warehouses. Since the yards are large, this sometimes results in that the yard managers have a hard time finding the right trailer with the material. This results in unnecessary time in searching for the trailer in order to unload it. Furthermore, if the searching and unloading of a trailer takes a long time, the risk of stock-out in the plant will increase. This unnecessary time can be eliminated with the use of GPS trackers. The exact location of the trailers could then be seen in the IT system, which increases the operating efficiency as Maras (2015) mentions. The real-time information of the packaging would also help the OEM to see if the packaging gets lost, and when in the process it got lost. By having access to this information, the OEM could invoice the responsible actor for losing the packaging.

Labels

At the OEM plants, there are restrictions when it comes to the labels. They have to present the correct information according to the standard of the label. Sometimes when the packaging with material arrives at the good receiving area, the label can be damaged or missing due to that it has fallen off and this results in that the packaging has to be sent to another station to receive a new label before entering the warehouse or point of use. Furthermore, all the extra labels that are printed result in unnecessary costs both for the label itself but also the man-hours spent to get the right label on the packaging. As Chan et al. (2006) stated, lack of conformity between different partners can lead to additional cost due to the need for repacking, and that can be when there are different demands on the packaging by the different partners. In the OEM's case, the different demands on the label between the supplier and the plant lead to the occasional need for relabelling. Another reason for the need of relabelling is when the label has fallen off during transportation. This need for relabelling is causing a higher and unnecessary cost for the OEM that could be eliminated with better conformity, such as better information flow (Chan et al., 2006). By having an RFID tag on the packaging itself instead of the label, the need for having a label on the packaging would be eliminated as all the information would be stored in the RFID tag. That could remove the need for the relabelling station at the plants and thereby reduce man-hour cost.

Information sharing

At the plants, the benefits that could be brought with a tracking device would be to plan the arrivals of the shipments, where and when the trailers should be unloaded but also if the packaging is delayed from the suppliers or cross-dock terminal. By having a GPS attached to the packaging, the plant can see when it will arrive and if it is on time or not. It can also be beneficial in the way that the plant can plan the production better depending on when the material will arrive. This will result in that the plant can avoid stops in the production because

the production plan can be re-planned to produce the products that the plants have material for (Jonsson & Mattsson, 2009).

Human error
It occasionally happens that the forklift driver forgets to scan the empty packaging at the point of use when picking it up. This results in that a new order will not be generated in the IT system to pick up new material and replace it where the empty packaging is located. If this is not noticed in time it could lead to interruptions in the material flow (Jonsson & Mattsson, 2009), such as shortages at the point of use but also delays in ordering new material from the material supplier. Although the Internal Logistics Development Manager at Plant 1 mentioned that human errors were not very common, they still happen and using the RFID technology would thereby reduce the human errors in relation to the manual scanning. When it happens that the forklift drivers forget to scan the empty packaging, it can lead to shortages of material, which could delay the production process. With the use of RFID tags attached to the packaging, this human error would be eliminated since the forklift drivers would then not need to scan the empty packaging when picking it up from the point of use.

4.7 Transportation Company

In this subchapter, the findings from the questionnaires for two transportation companies, further on called TC1 and TC2, are presented and analysed.

4.7.1 Findings and Analysis of RFID tags and GPS trackers at Transportation Company

Location
TC1 have GPS trackers on all their assets that carry the shipments. Additionally, TC1 has a Transport Management System (TMS) in trucks and mobile devices that the truck driver uses for acknowledging the shipments picked up and delivered. Other customers of TC1 are tracking their packaging themselves and TC1 does not see any problems if the OEM would start tracking the packaging themselves. TC2 say that they can track their assets in real-time with the help of GPS that is located on each truck they own. A GPS tracker provides the user with real-time location according to Kirch, Poenicke and Richter (2017). From a transportation company's point of view, the most important thing is to know where the truck and trailer is. By connecting the customers' shipment with the truck's GPS tracker, the transportation company knows where both their assets and the customers packaging are located. Furthermore, to track the transportation it does not have to be a GPS tracker, it can be an RFID tag as well (Hunt et al., 2006).

Label
Barcodes on labels are mostly used by TC1 when the packaging is in their warehouse and they have investigated if there are other track and trace technology that can be used instead. From TC2 there was no indication that they needed the labels, the truck driver gets the order in the booking system and he or she acknowledges the booking. The truck driver accept the booking when it has been picked up and delivered. Since both transportation companies already have the technology, such as GPS, and it will not be beneficial for the transportation company itself to have an RFID tag and GPS tracker on each packaging.

Information sharing
Both TC1 and TC2 said that there would be no problems to share the information about the shipments with the OEM. However, both said that this is currently not done due to that it was not a requirement from the OEM. TC1 stated that the sharing of information would not affect them in any way, they still need to control the flow so for TC1 there would not be any reduction in workload. For TC2 the answer was a bit different, they said that if the OEM would track and trace the packaging themselves there would not be any need for the OEM to ask TC2 for the information about packaging when they needed it. That could then reduce the workload for TC2. According to Hunt et al. (2006), the information sharing between all actors in the supply chain network has to communicate and coordinate all activities in order to have an efficient supply chain.

4.8 Analysis on RFID tags and GPS trackers in the whole packaging flow

The OEM's packaging flow contains many different steps and processes. Kroon and Vrijens (1995) explain that not only transportation of packaging is included in the returnable packaging flow, but cleaning, maintenance, storage, and administration also applies to the packaging flow, which is the case for the OEM's packaging flow.

Location
A GPS tracker compared to an RFID tag can give a real-time location of the packaging, but the RFID tag can provide more track and trace information regarding the packaging such as distribution history and quantity (Misra & Enge, 2006; Kirch, Poenicke & Richter, 2017). Since the GPS tracker has trouble sending the signal when it is indoors, it may not be so much more beneficial for the suppliers and plants to use it within the facilities than using the GPS tracker in the yard or to see when a delivery will arrive. The real-time location is important to know if there is a delay of delivery to the supplier, cross-dock or plant and when the packaging is standing on the yard before entering the facilities. This is connected to the trucks and trailers used by the transportation companies and some of them have their own track and trace technology attached

to the truck or trailer in order for them to allocate the transportations. If the information the transportation companies gather from their track and trace technologies were shared with the OEM there would not be a need for the OEM to invest in the same technologies on each packaging. In other words, having a GPS tracker on each packaging to get the real-time position when it is loaded and transported may not be needed if it is a GPS tracker on the trailer and the transportation company can share the information to the OEM. The need for detailed information is dependent on which actors and packaging are involved (Roos et al., 2005), for example, the OEM might not need to know the real-time location of the packaging within the plants, making it unnecessary to use the GPS trackers within the plants. However, the GPS trackers would be useful when using them to track and trace the packaging that is in-transit between actors in the supply chain, and for the exact location of the trailers at the plant's yards. By comparing the racks with pallets and boxes, both the material within the racks and the racks themselves are more expensive. That results in that tracking the racks in detail with GPS trackers can be more beneficial for the OEM, especially if the packaging gets lost, delayed or even stolen on its way (Gnimpieba et al., 2015).

The average yearly scrap of the packaging for the last 4 years is 2% per year or a little over 3.000.000 pieces per year. There is, of course, a loss when scrapping material, but the OEM does not invoice the scrap. However, if the supplier loses the packaging, the OEM invoices them. As for now, there is a great amount of uncertainty if some packaging gets lost in the packaging flow due to lack of knowledge of the packaging's position. The use of RFID tags and GPS trackers would help with knowing where the packaging is and the history of the packaging's flow (Véronneau & Roy, 2009), and the OEM could then invoice a responsible actor if the packaging gets lost in the packaging flow.

Other advantages with the track and trace technology that would be beneficial for the OEM's packaging flow are the ability to locate a packaging, read the distribution history, and the item quantity that each actor has in stock (Véronneau & Roy, 2009). Véronneau and Roy (2009) mention other valuable aspects with track and trace technology such as, reduction of duplication and redundancy, that would be relabeling, repacking, administration and so forth in the OEM's packaging flow. One thing to keep in mind is the false response that could appear if the RFID reader is not able to read the RFID tag and give accurate information. That could lead to that the shipment is considered to be correct when it is not, or incorrect when it actually is (Kapoor et al., 2009). That could cause extra handling of the packaging.

Label

Comparing the current labels that are used on the packaging with the RFID tags and GPS trackers, there are advantages and disadvantages with them all. An RFID tag can carry more information than a barcode (Véronneau & Roy, 2009; Pålsson, 2018). The information from RFID tags could be presented in the supply chain database, meaning that all actors involved in

the packaging flow can get the information (Zelbst et al., 2010) and start preparing for the packaging to arrive at the receiving actor in the supply chain (Zelbst & Sower, 2016). Taking the cross-dock terminal in the OEMs packaging flow into consideration, the RFID tag is considered to be better for them since there are extra labels being printed to present the information the cross-dock terminal needs in order to get the packaging to the right location. This due to the fact that the label does not always present the information the employees in the cross-dock terminal required.

Human errors

In the OEMs packaging flow, there are many times when a human error occurs, such as there is wrong packaging loaded and sent to the supplier, resulting in wrong inventory levels and man-hours spent on counting the inventory and updating the IT systems. Moreover, there are empty boxes at the plants that the employees forget to scan resulting in no refill at the point of use. These results of human errors all contribute to extra time spent on managing the problems that occur, which then results in extra man hours that could be prevented with track and trace technology. However, since the packaging is traveling between different actors in the supply chain, all actors have different demands on the packaging, such as what information is needed to be shown on the packaging (Chan et al., 2006; Véronneau & Roy, 2009). This makes it difficult to decide on which technology to choose. All actors' demands have to be taken into consideration when the technology is chosen in order to increase the effectiveness and keep the extra costs for repacking, administration and delays as low as possible through the whole packaging flow (Chan et al., 2006).

Inventory

The Price Manager and the Strategic Packaging Planner at the OEM mentioned that their biggest problem is not knowing what happens with the packaging and where it is located. That problem can be solved with the use of RFID tags and GPS trackers as they can show the distribution history of the packaging and its location as Véronneau and Roy (2009) stated. When buying new packaging, it is important to know how much packaging is in stock to know the real need for new packaging. The RFID tags and GPS trackers increase the visibility of the packaging (Véronneau & Roy, 2009) and can prevent that too many or too few packaging are bought. This would reduce the obsolescence of the packaging (Zelbst & Sower, 2016). Today, all the investments in packaging are based on estimations. With better visibility over the packaging that is in stock, inventory levels can be reduced as unnecessary packaging investments would be eliminated. However, tracking, for example, all parts of the wooden pallets increases the complexity and it can be very expensive to have an RFID tag on all of the pallet's parts.

5. Results

The result of this research is based on empirical findings and analysis. A summary of the benefits that could be achieved for each actor has been done, together with the difficulties that could emerge when using the track and trace technologies.

5.1 Packaging Terminal

Trace of packaging's location and information about item quantities
No scanning is done at the packaging terminal, resulting in no elimination of manual scanning can be achieved with the use of RFID tags. Due to no scanning, the packaging terminal does not have an overview of how much packaging is located at their facilities, and where the packaging is located in the storage area. Knowing the packaging's location would surely help when looking for packaging with the use of GPS location, however, due to the packaging can be standing at the packaging terminal for several days, it is not considered necessary and RFID tag is considered being more valuable as it would show that the packaging had arrived and departed from the packaging terminal. In that case, the packaging terminal would know how much packaging is located at their facilities. As there is a great amount of packaging stacked on top of each other, there is a higher risk for tag shadowing. The pallets, frames, and lids are bundled together, and the boxes are stacked on top of each other. However, an RFID tag that operates well when several tags are stacked can be found and the OEM should know and understand the environment that the tags will operate in if making an investment in RFID tags.

Reduction of excessive inventory and better decision-making capabilities
The use of RFID tags would give information about how much packaging has entered and left the packaging terminal. By knowing how much packaging is located at the packaging terminal, the OEM can take more accurate decisions when deciding how much new packaging is actually needed to invest in, which could reduce the cost of investing in excessive packaging. The less excessive packaging that the packaging terminal has will lead to less obsolescence of the packaging.

Reduction of human error and increased customer service
There is a risk of loading the wrong amount or type of packaging to the truck. This can result in that the supplier has to send the wrong packaging back to the packaging terminal. With the use of RFID tag, this could be eliminated and would thereby improve the customer service to the suppliers.

Concerning the washing and cleaning of the boxes at the packaging terminal, the RFID and GPS need to be placed on the packaging so that the risk of it not falling off would be low. In addition,

they need to resist the high pressure and temperature when washing the boxes. A concern for the pallets is that they are stored outside and exposed to different kinds of weather. Raining, snowing, and the humidity all can affect the pallet, which becomes moist and that can affect the ability to read an RFID tag attached to the packaging.

5.2 Material Supplier

Less inventory cost of OEM's packaging
The biggest benefit that the track and trace technologies would bring to the supplier was to decrease the inventory cost of the packaging, according to supplier 1. The rental cost for the racks is more expensive than the pallets and boxes, which makes it more beneficial to track and trace the racks to begin with. By having the information about the amount of packaging that they have in storage, they will eliminate the risk of having to order excess packaging from the OEM. That results in lower inventory cost for the supplier.

Trace of packaging's location at the yard and better visibility for the OEM
Supplier 1 has a great amount of different packaging at their facilities, both from the OEM and from other customers. This results in that it is difficult to track the packaging's location. The use of a GPS tracker on the packaging would facilitate with finding where the packaging is located, and by having RFID tag on the packaging, the supplier would have information about all types of packaging that they have in storage. Both of these track and trace technologies would help the supplier knowing what type of packaging has arrived and departed from them. That would also give the OEM better overview of the packaging that is located at the supplier's facilities and if there was some packaging that was wrongly sent to them.

Reduction of human error and scanning before leaving the supplier's facilities
Both supplier 1 and 2 scan the packaging before it leaves their facilities. Additionally, supplier 1 needs to scan the label at its own packaging when repacking the produced material to the OEM's packaging. This increases the risk of a human error as the employee scanning the packaging could forget to scan one of the labels. An RFID tag attached to the packaging would eliminate this risk. Another human error that could be eliminated with the use of the track and trace technologies would be when a wrong type of packaging is sent from the packaging terminal without being noticed. Then the amount of packaging in the IT system would not match with the real amount stored at the supplier, resulting in the supplier has to pay for the cost of having the wrong type of packaging at their facilities. The RFID tag could help with eliminating this problem since the RFID tag could give a signal if the wrong type or amount of packaging were loaded to the truck. The same goes for when the packaging is loaded to the truck when leaving the supplier's facilities.

5.3 Cross-dock terminal

Reduction of scanning, human errors and handling time
Manual scanning of the packaging takes place both when the packaging arrives and departs the cross-dock terminal. In addition, when unloading a truck, the employee has to count the packaging and match it with the amount of packaging that should have been in the shipment. This can result in long handling time, which could be reduced with the use of RFID tags. When counting, there is a higher risk for human errors and that could affect that the plant gets incorrect information of the amount of packaging that arrived at the cross-dock terminal. Human errors of counting the packaging could be reduced with the use of RFID tags as there would be no manual counting. The less handling time could then lead to a reduction of man-hours, but also to less waiting time to load and unload a trailer. However, the risk of tag shadowing needs to be kept in mind when scanning several tags at the same time as mentioned before.

Information about the packaging distribution history
Occasionally it happens that the packaging gets lost on its way to the cross-dock or does not arrive. In that case, having an RFID tag or GPS tracker would be beneficial, as it would provide information about where the packaging was before and where it got lost.

Less printing of labels
The cross-dock terminal prints one new label for each shipment with the destination of the shipment and how much packaging is included in the shipment. This results in much printing of labels that are only used and scanned once at the packaging terminal. An RFID tag attached to the packaging would eliminate the need for printing these labels at the cross-dock, and would thereby contribute to a more sustainable direction.

Better operational planning
By having RFID tags and GPS trackers, information about when a truck would arrive and what it is carrying could be provided to the cross-dock terminal. This would help the cross-dock terminal to improve the operational planning, and especially if there were any deviations happening during transportation, as the information sharing would be more transparent.

5.4 Plant

Reduction of scanning and handling time
Since there is a lot of manual scanning performed at both plant 1 and 2, the use of RFID tags on the packaging would reduce the scanning. This would result in less handling time of the packaging and the man hours would thereby be reduced. However, when reading the RFID tag

on the packaging, the metal located all around the plant could affect the RFID reader not being able to read the RFID tag. Moreover, tag shadowing could also occur within the plant due to many packaging located close together.

Better yard management
As the yards at the plants is big and trailers loaded with the material are occasionally left in the yard until they are later unloaded, the time that it takes in finding the correct trailer to unload can be unnecessarily long. This increases the risk of stock-out in the plant. With the use of GPS trackers, the location of the trailers located in the yard can be traced, which would increase the operating efficiency.

Information about the packaging's distribution history
The use of GPS trackers would provide the plant the information about the packaging's distribution history, which would be helpful in case of lost or stolen packaging on its way to the plant. In case of lost packaging on its way to the plant, the OEM could invoice the responsible actor for losing the packaging. On the other hand, in case of stolen packaging on its way to the plant, the GPS tracker would ease to track and trace of the packaging, which would be highly beneficial in case of packaging transporting critical and expensive component to the plant. What needs to be kept in mind regarding GPS trackers is that they normally do not work indoors when used with satellites.

Less man hours due to relabeling
The occasional need for relabeling is causing extra work for the employees at the plant. This extra work could be eliminated if using RFID tag that would store the same information as the label. The labels would therefore not be needed at the packaging, and the man-hour cost related to the relabeling station would be eliminated. By having RFID tag on the packaging instead of a label also eliminates the occasion when the label falls off the packaging during transportation.

Better production planning
In case of a delay of the packaging's arrival at the plants, it would help by knowing the packaging's distribution history with the use of GPS. The OEM could then keep track of which actor was causing the delay and act upon it. By knowing when the packaging will arrive at the plant, or if there is a delay on it or not, the plant can plan the production better, especially if the delay of material would result in a stop in the production.

Reduction of human errors
Occasionally it happens that the forklift driver forgets to scan the empty packaging when picking it up from the point of use. This can result in interruptions in the material flow if not noticed in time. The use of RFID tags would eliminate this human error as the need for scanning would disappear, and the material flow would not be affected.

5.5 Transportation Company

Less man hours due to OEM's possibilities to control their packaging themselves
As the transportation company is using GPS trackers to track their assets, it would not bring any benefit for them to have a GPS tracker on the packaging. However, by having RFID tags on the packaging and connecting it with the GPS trackers on the trucks, the transportation company would have both the information about where their assets are and the customer's packaging. Moreover, the OEM would have access to the information about where their packaging is located, leading to less need of asking the transportation company for information about the packaging. This could reduce the workload at the transportation company as the OEM would follow up and control their packaging themselves.

To summarise the results, the different benefits that can be achieved with the RFID tags and GPS trackers have been listed down in Table 5 below. The green boxes indicate that the technology within the box is applicable for that particular benefit and at that particular actor in the packaging flow. The grey boxes indicate that the particular benefit was not considered to be achievable at that particular actor.

Table 5. *The different benefits for each actor in the packaging flow.*

Benefits \ Actors in the packaging flow	**Packaging terminal**	**Material supplier**	**Cross-dock terminal**	**Plant**	**Transportation company**
Trace of packaging's location	**RFID / GPS**	**RFID / GPS**	**RFID / GPS**	**RFID / GPS**	**RFID / GPS**
Reduction of human errors	**RFID**	**RFID**	**RFID**	**RFID**	
Reduction of excessive inventory	**RFID / GPS**	**RFID / GPS**			
Less obsolescence of packaging	**RFID / GPS**				
Reduction of scanning		**RFID**	**RFID**	**RFID**	
Reduction of handling time			**RFID**	**RFID**	
Less man hours	**RFID**	**RFID**	**RFID**	**RFID**	**RFID**
Better operational planning		**RFID / GPS**	**RFID / GPS**	**RFID / GPS**	
Less printing of labels			**RFID**	**RFID**	

6. Discussion

In this chapter the results, methods and delimitations are discussed.

From the interviews and questionnaire, it was given that supplier 1 was really interested in the implementation of RFID tags and GPS trackers to the OEM's packaging, while supplier 2 did not see any benefits of implementing these technologies to their operation. Naturally, it would require a pilot project together with more suppliers in order to get a better view on if the track and trace technology could be beneficial or not for the suppliers. Due to only two of the OEM's suppliers and two transportation companies were analysed and the operations differ for each actor, it is not possible to generalise the empirical findings from the studied suppliers and transportation companies so that it is representative for all of the OEM's suppliers and transportation companies as Bryman and Bell (2011) mention.

If the label could be removed from the packaging it could reduce the need for cleaning the boxes. The boxes are cleaned for two reasons. Firstly, because they get dirty during transportation and from the material they are carrying. Secondly, the boxes need to be cleaned in order to remove any rests of the label, both the paper label and the glue used to paste the label on the box. In the cleaning machine at the packaging terminal, the boxes are cleaned in warm water during high pressure. By not having the label on the box and instead have an RFID tag, the needs of the high temperature and pressure of the water may not be needed. This could be both cost saving for the packaging terminal and the OEM, since they pay for the service. Furthermore it is also more sustainable.

By removing the label it will also reduce the need for pulp to make a label. That will also be more sustainable because the label is used as a one-way but RFID tags and GPS trackers are used in the returnable flow since they will be used many times. However, the materials that an RFID tag or a GPS tracker are made of is not as sustainable as the pulp used for the labels. Since the RFID tag and GPS tracker are made of plastic and metal.

Increasing information sharing can be difficult when many actors are involved. This due to the fact that it can be difficult to know what type of information to share. Additionally, it can also be difficult to detect if there has been too much information shared that can be harmful to the actors.

The delimitation in this research was to only look at the packaging terminal, suppliers, and cross-dock terminal, plant, and transportation companies in Sweden. However, since the OEM is located globally there are some aspects to take into consideration when investigating further if the result of this research is applicable in other regions of the world. The processes in the packaging flow are said to be more or less the same all over the world. However, there can still be differences that have to be taken into consideration before deciding if the result is useful for

all regions. One aspect is the radio frequency for the RFID tags. There are different standards depending on if you are in North or South America, Europe or Asia. This means that a tag made for the European market may not work in Asia as an example. Europe and North & South America have a standard on the frequencies used in the regions, but Asia, however, does not have any clear standards when it comes to radio frequencies.

The result of this research could look different if there would have been more companies responding to the questionnaire. In order to get more answers, it may have been better to have another approach to get the information, send to more suppliers and transportation companies, go through employees at the OEM to help the researchers get the companies to answer the questions. Perhaps there would have been more people answering if there was a survey sent out to the companies instead of emails. The result would also differ if the research would include packaging terminals, suppliers, cross-docks, and plants outside of Sweden due to differences such as culture.

There are some things that need to be investigated before implementing track and trace technologies to the packaging. Firstly, the OEM has to find where to attach a tracking device on the packaging. There are RFID tags that can be moulded into plastic, meaning that the boxes can have an RFID tag moulded into them when the boxes are produced. Some of the tags that can be moulded can resist high pressure as well. In other words, the tags will still work after the cleaning of the boxes at the packaging terminal. Although, when having the RFID tag moulded into the box, the risk of having the box live longer than the tag can be high. This can result in that the box has to be scrapped when the tag does not work anymore. This can result in more scrap compared to having boxes without tags. By adding the track and trace technology to the pallets, the question would be if it is necessary to add a tag on all sleeves, pallets, lids, and spacers. To have it on all parts it is easier to see if some part of the packaging disappear in the flow but it may also increase the risk for shadowing. For the racks, it would be very good to add track and trace technologies to them, however, the racks are often in metal so it cannot be added inside the rack due to the high risk of having the signal bouncing. By attaching an RFID tag or a GPS tracker on the outside of the packaging may result in that it falls off the packaging. That can then contribute to that the packaging “disappears” in the IT system since it cannot be scanned anymore. Moreover, it will also lose the information about the material inside the packaging. This can then result in that the OEM needs to have the ability to add a new tracker to the packaging.

In the case of cost, a passive RFID tag is the cheapest type of track and trace technology and it is easier to make a new passive RFID tag than another type of tag or GPS tracker. Another point of view is when a track and trace device is used through the supply chain. The risk of damaging the device is then high due to the fact that there are many people involved to transport and handle the packaging. Then, it is important to inform all actors working with the packaging on how to

handle the packaging and develop or change the processes in order to protect the devices. Other aspects, such as when an RFID tag or GPS tracker needs to be changed due to damaging or low battery and who is responsible for making sure that all tags are working, needs to be decided as well. Regarding implementation of the RFID tags at the suppliers side, it needs to be kept in mind that if the OEM would require certain type of RFID tags and the customers of OEM's suppliers would likewise implement the technologies and require another type of RFID tags, then that might be problematic for the supplier to have different RFID tags to read between their customers.

Secondly, this research did not take cost aspects into consideration, such as how expensive it would be to invest in the track and trace technologies and if the investment would pay off for the OEM. This qualitative research has shown that it would be beneficial for the whole packaging flow to have RFID tags and GPS trackers attached to the packaging, but the future research should be to analyse the quantitative aspects of the investment. If implementing this kind of investment, the OEM needs to know what information they want to get out from the solutions and how the information will be integrated into the IT systems of each actor (Zelbst & Sower, 2016). The next step should be to select the appropriate type of RFID tags and GPS trackers that are aligned with the environment that the track and trace technologies will operate in and the detail of information that the OEM wants to be shared (Zelbst & Sower, 2016).

Thirdly, there are different regulations in each country. If packaging will pass the borders to other location there has to be an investigation on which countries are allowing companies to track and trace the packaging and which are not. The result could be to not invest in RFID tags and GPS trackers on a global perspective due to the fact that some countries are against track and trace technology. Additionally, there is an integrity concern that many employees at companies have regarding track and trace. As an example, truck drivers may feel that they cannot perform their work tasks in the order they would like if they are always monitored.

Fourthly, before implementing the track and trace devices it is needed to have an IT system that can handle all data that will be collected. The data then has to be analysed so that it can be used within the processes. Furthermore, it has to be decided who is responsible for the IT system and the track and trace devices at the OEM. Another thing that has to be taken into consideration is how to share the information between the different actors. Since the devices will be more beneficial for the supply chain if the information is shared within the supply chain network it is important to build up an IT structure that will manage many users and a lot of information sharing as a cloud-based IT system for example.

7. Conclusion

The aim of this research was to identify how the OEM's packaging flow can benefit from RFID and GPS technologies in terms of track and trace. In order to answer the aim, interviews, questionnaires, and site visits were done and the findings from it were analysed together with literature. The conclusions from this research are that RFID tags and GPS trackers can bring many benefits to the OEM's packaging flow.

For most of the actors, benefits such as control of inventory, packaging location, reduction of human error and reduction of manual scanning can be achieved. By knowing the exact amount of packaging that is in storage at terminals, suppliers and plants give opportunities to know how much each actor needs, but also how much the OEM must have in order to not run out of the packaging. The track and trace technology can help the whole supply chain to be more efficient in the operations, such as being able to plan for when packaging will arrive, reduce the number of manual scanning by having automatic scanning of the RFID tags or real-time location positioning with the help of GPS trackers.

With the implementation of RFID tags and GPS trackers, there are some challenges that should be kept in mind. There is a risk of tag shadowing when many RFID tags are located close together, and a false response can be generated if the RFID reader cannot read the RFID tag properly. The location of metal in the environment can also affect the reading abilities of an RFID reader. GPS trackers might, on the other hand, have difficulties operating indoors.

By doing study visits and interviewing employees at the different actors of the packaging flow, a good picture and understanding of the packaging flow was achieved. On the other hand, by receiving answers from more actors in the packaging flow would have made the analysis and results more reliable compared to the reality. From the study visits, it was seen that there were more opportunities with implementing RFID tags rather than GPS trackers to the OEM's packaging. Therefore, the recommendation from this research is to focus more on the RFID technology together with the OEM's packaging since RFID tags can carry more information than GPS trackers. The use of RFID tags could then be connected with the GPS trackers that are currently used by the transportation companies. By increasing the information sharing between the actors and the OEM can result in that the investments of track and trace technology do not have to be so high due to that GPS trackers are already used on the transportation of the packaging.

8. Recommendations

In the future, the OEM is recommended to start with three things; packaging terminal, boxes, and RFID tags. The reason for starting at the packaging terminals is to reduce the amount of manual work and increase the efficiency at the packaging terminals. This because in order to be able to utilise the RFID tags and GPS trackers as much as possible, the actors in the packaging flow need to be on the same level of maturity.

Furthermore, the RFID tag is, according to literature and interviews, more beneficial for the OEM´s packaging flow than the GPS tracker. This since the GPS is shown to be more beneficial for transportation between different actors and the RFID tag is more beneficial for handling and transportation at the different actors. By increasing the collaboration and information sharing between the different actors, the track and trace information from the transportation companies' GPS trackers could be shared, leading to that the OEM does not have to invest in GPS trackers themselves and can focus on RFID tags instead. Concerning the different types of packaging, there are different types of tags to choose. For pallets and boxes, the recommendation based on the theory is to have passive RFID tags working at ultra-high frequencies since it is usually used for inventory management. For the racks, the recommendation is to use semi-active RFID since the tag is not easily disturbed, usually used to track expensive parts, and it is cheaper in cost than an active RFID tag.

References

Amin, S.H., Wu, H. and Karaphillis, G. (2018). A perspective on the reverse logistics of plastic pallets in Canada. Journal of Remanufacturing, 8(3), pp.153-174.

Angeles, R. (2005). RFID technologies: supply-chain applications and implementation issues. *Information systems management*, *22*(1), pp.51-65.

Bryman, A. and Bell, E. (2011). Business research methods. 3rd edn, Oxford: Oxford University Press.

Bryman, A. & Bell, E. (2015), Business research methods. 4th edn, Oxford: Oxford University Press.

Chan, F.T.S., Chan, H.K. and Choy, K.L. (2006). A systematic approach to manufacturing packaging logistics. *The International Journal of Advanced Manufacturing Technology*, *29*(9-10), pp.1088-1101.

Dubois, A. and Gadde, L.E. (2014). "Systematic combining"—A decade later. *Journal of Business Research*, *67*(6), pp.1277-1284.

El-Rabbany, A. (2002). *Introduction to GPS: the global positioning system*. Artech house.

Fosso Wamba, S. (2012). Achieving supply chain integration using RFID technology: the case of emerging intelligent B-to-B e-commerce processes in a living laboratory. *Business Process Management Journal*, *18*(1), 58-81.

Foster, P., Sindhu, A. and Blundell, D. (2006). A case study to track high value stillages using RFID for an automobile OEM and its supply chain in the manufacturing industry. In *2006 4th IEEE International Conference on Industrial Informatics* (pp. 56-60). IEEE.

Giard, V. and Sali, M. (2013). The bullwhip effect in supply chains: a study of contingent and incomplete literature, International Journal of Production Research, 51(13), pp. 3880–3893.

Gnimpieba, Z.D.R., Nait-Sidi-Moh, A., Durand, D. and Fortin, J. (2015). Using Internet of Things technologies for a collaborative supply chain: Application to tracking of pallets and containers. Procedia Computer Science, 56, pp.550-557.

Gustafsson, Jönson, Smith & Sparks (2013). Retailing Logistics and Fresh Food Packaging - Managing Change in the Supply Chain. Kogan Page Publishers.

Han, J.H. (2014). Edible films and coatings: a review. In *Innovations in food packaging* (pp. 213-255). Academic Press.

Hanson, J.L., Balmer, D.F. and Giardino, A.P. (2011). Qualitative research methods for medical educators. *Academic pediatrics*, *11*(5), pp.375-386.

Hunt, V.D., Puglia, A. and Puglia, M. (2007). RFID: a guide to radio frequency identification. John Wiley & Sons.

Jonsson, P. and Mattsson, S.-A. (2009) *Manufacturing planning and control*. McGraw-Hill Education.

Kapoor, G., Zhou, W. and Piramuthu, S. (2009). Challenges associated with RFID tag implementations in supply chains. European Journal of Information Systems, 18(6), pp.526-533.

Kirch, M., Poenicke, O. and Richter, K. (2017). RFID in Logistics and Production–Applications, Research and Visions for Smart Logistics Zones. *Procedia Engineering*, *178*, pp.526-533.

Kong, H. and Yu, B. (2018). A Moving Object Indoor Tracking Model Based on Semiactive RFID. *Mathematical Problems in Engineering*, *2018*.

Kothari, C.R. (2004). *Research methodology: Methods and techniques*. New Age International.

Kroon, L. and Vrijens, G. (1995). Returnable containers: an example of reverse logistics. *International Journal of Physical Distribution & Logistics Management*, *25*(2), pp.56-68.

LAM, C. and IP, W. (2019). An Integrated Logistics Routing and Scheduling Network Model with RFID-GPS Data for Supply Chain Management. *Wireless Personal Communications*, pp.1-15.

Leech, N.L. and Onwuegbuzie, A.J. (2009). A typology of mixed methods research designs. *Quality & quantity*, *43*(2), pp.265-275.

Li, X. (2019). A GPS-Based Indoor Positioning System With Delayed Repeaters. *IEEE Transactions on Vehicular Technology*, *68*(2), pp.1688-1701.

Livingstone, S. and Sparks, L. (1994). The new German packaging laws: effects on firms exporting to Germany. *International Journal of Physical Distribution & Logistics Management*, *24*(7), pp.15-25.

Ma, Y., Wang, N., Che, A., Huang, Y. and Xu, J. (2013). The bullwhip effect on product orders and inventory: a perspective of demand forecasting techniques, *International Journal of Production Research*, 51(1), pp. 281–302.

Maras, E. (2015). RFID: a tool for tracking products, assets and more: with the emergence of real-time data networks, RFID tags provide accurate status reports and can poinpoint inefficiencies in the food supply chain, Food Logistics, p. 44.

McKerrow, D. (1996). What makes reusable packaging systems work. *Logistics Information Management*, *9*(4), pp.39-42.

Misra, P. and Enge, P. (2006). Global Positioning System: signals, measurements and performance second edition. *Massachusetts: Ganga-Jamuna Press*.

Ouyang, Y. (2007). The effect of information sharing on supply chain stability and the bullwhip effect, European Journal of Operational Research, 182(3), pp. 1107–1121.

Perret, E. (2014). *Radio Frequency Identification and Sensors: From RFID to Chipless RFID*. John Wiley & Sons.

Pålsson, H. (2018). *Packaging Logistics: Understanding and managing the economic and environmental impacts of packaging in supply chains*. Kogan Page Publishers.

Regattieri, A. and Santarelli, G. (2013). The important role of packaging in operations management. In *Operations Management*. IntechOpen.

Rong, H., Tian, J. and Zhao, T. (2016). Temporal uncertainty analysis of human errors based on interrelationships among multiple factors: a case of Minuteman III missile accident. *Applied ergonomics*, *52*, pp.196-206.

Roos, K., West, M., Chang, E. and Armstrong, B. (2005). An eco-solution for track & trace of goods and third party logistics. In *INDIN'05. 2005 3rd IEEE International Conference on Industrial Informatics, 2005.* (pp. 402-405). IEEE.

Sandom, C., & Harvey, R. S. (Eds.). (2004). *Human factors for engineers* (Vol. 2). Iet.

Sari, K. (2010). Exploring the impacts of radio frequency identification (RFID) technology on supply chain performance. *European Journal of Operational Research*, *207*(1), pp.174-183.

Schaefer, D., & Cheung, W. M. (2018). Smart Packaging: Opportunities and Challenges. *Procedia CIRP*, *72*, 1022-1027.

Sen, D., Sen, P. and Das, A. M. (2009). RFID for Energy and Utility Industries. PennWell

Steenis, N. D., van Herpen, E., van der Lans, I. A., Ligthart, T. N., & van Trijp, H. C. (2017). Consumer response to packaging design: The role of packaging materials and graphics in sustainability perceptions and product evaluations. *Journal of cleaner production*, *162*, 286-298.

Stefansson, G., & Lumsden, K. (2008). Performance issues of smart transportation management systems. *International Journal of Productivity and Performance Management*, *58*(1), 55-70.

Véronneau, S., & Roy, J. (2009). RFID benefits, costs, and possibilities: The economical analysis of RFID deployment in a cruise corporation global service supply chain. *International Journal of Production Economics*, *122*(2), 692-702.

Yam, K. L., Takhistov, P. T., & Miltz, J. (2005). Intelligent packaging: concepts and applications. *Journal of food science*, *70*(1), R1-R10.

Zelbst, P. J., Green Jr, K. W., Sower, V. E., & Baker, G. (2010). RFID utilization and information sharing: the impact on supply chain performance. *Journal of Business & Industrial Marketing*, *25*(8), 582-589.

Zelbst, P.J. & Sower, V.E. (2016). *RFID for the Supply Chain and Operations Professional, Second Edition*, vol Second edition, Supply and Operations Management Collection, Business Expert Press, New York, NY