RTLS – the missing link to optimizing Logistics Management?

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AUTHOR: Karl Hammerin, Ramona Streitenberger
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Examiner: Kerstin Johansen

Supervisor: Mahmood Reza Khabbazi

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Abstract

The purpose of this thesis was to investigate how potentials of Real-Time Location Systems (RTLS) in relation to Just In Time (JIT) management could be utilized within logistics management. For this, a framework, based on previous research of the inter-relations of RTLS and JIT management, is proposed, to assess the effects of RTLS on logistics management, both on a managerial - as well as on an operational level. To answer the proposed research questions, the study followed a deductive and exploratory case study design, which was conducted at a company within the automotive industry. To understand the challenges within logistics management at the case company, interviews, observations, analysis of internal documents and a focus group were used, which allowed for a triangulation of the captured information. The findings and analysis of the data show that on an operational level the challenges within logistics management are related to complex logistic structures, pull strategies with partial push material flows, lack of information and – reliable data, as well as processes reliant on individuals. On the managerial level the findings suggest challenges related to high complexity and space constraints, time constraints, lack of transparency and – data connections, the company’s improvement focus, employee attitude and a lack of reliable data. When the challenges were evaluated in relation to the proposed framework, it shows that these challenges would be resolved or counteracted by the benefits RTLS could provide in relation to JIT management. This study thereby supports the positive correlation between RTLS’s potential and JIT in logistics management.

Keywords
RTLS, Real-Time Location Systems, Just In Time, JIT, Logistics Management, Material flows
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## Abbreviations

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<table>
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<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>3PL</td>
<td>Third Party Logistics</td>
</tr>
<tr>
<td>AOA</td>
<td>Angle of Arrival</td>
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<tr>
<td>BT</td>
<td>Bluetooth</td>
</tr>
<tr>
<td>BT-LE</td>
<td>Bluetooth Low Energy</td>
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<tr>
<td>CONWIP</td>
<td>Constant Work In Progress</td>
</tr>
<tr>
<td>CPS</td>
<td>Cyber Physical Systems</td>
</tr>
<tr>
<td>DOA</td>
<td>Direction of Arrival</td>
</tr>
<tr>
<td>ERP</td>
<td>Enterprise Resource Planning</td>
</tr>
<tr>
<td>GPS</td>
<td>Global Positioning System</td>
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<tr>
<td>IoS</td>
<td>Internet of Services</td>
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<tr>
<td>IoT</td>
<td>Internet of Things</td>
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<tr>
<td>IR</td>
<td>Infrared</td>
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<tr>
<td>JIT</td>
<td>Just In Time</td>
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<tr>
<td>PDOA</td>
<td>Phase Difference Of Arrival</td>
</tr>
<tr>
<td>RFID</td>
<td>Radio Frequency Identification</td>
</tr>
<tr>
<td>RSS</td>
<td>Received Signal Strength</td>
</tr>
<tr>
<td>RTLS</td>
<td>Real-Time Location System(s)</td>
</tr>
<tr>
<td>TDOA</td>
<td>Time Difference of Arrival</td>
</tr>
<tr>
<td>TPS</td>
<td>Toyota Production System</td>
</tr>
<tr>
<td>UWB</td>
<td>Ultra-Wide Band</td>
</tr>
<tr>
<td>VSM</td>
<td>Value Stream Mapping</td>
</tr>
<tr>
<td>WIP</td>
<td>Work In Progress</td>
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1 Introduction

The introduction chapter gives an insight to the research aim and provides a general context for this thesis. For this, the first subchapter describes the general background of the researched phenomenon, while the problem is further clarified within the second subchapter, before the actual research purpose is outlined in the third subchapter. This is followed up by the delimitations of the research, and a subchapter that explains the relevance of the thesis to both the research community and to practitioners. The last subchapter provides an overview of the structure of the rest of the thesis.

1.1 Background

Globalisation has created both opportunities and challenges for industries. While companies have reaped the benefits of gaining new markets, they have also faced increased pressure from international competition. In this environment, industries are continuously searching for new methods and techniques to increase efficiency and thus gain a competitive edge (Felice & Petrillo, 2015).

One of the most commonly used approaches for this over the last 30 years, has been the introduction of Lean Production Systems, which is recognized as one of the best methods for manufacturing improvements and the elimination of waste in the value chain (Samuel, et al., 2015). While Lean methods have been applied at Toyota for over half a century, it was not introduced to the western world until the early 90s, when several articles and books were published on Toyotas superior production system and it became one of the most recognized methods for improvements of organizational processes (Samuel, et al., 2015). Lean has since then been widely used in several different sectors, such as industries of the automobile-, the aerospace- and the health care sector (Jasti & Kodali, 2014).

In recent years, new technologies and the digitalization of manufacturing industries have been argued to have the potential of taking efficiency and communication one step further, by allowing organizations to create smart factories, where intelligent networking of processes, machines and products communicate in a cyber-physical space, both internally within the organization and externally with customers and suppliers (Barreto, et al., 2017). This digital evolution has been recognized as vital for today’s manufacturing industries, and got named the fourth industrial revolution or Industry 4.0 (Hofmann & Rüsch, 2017).

However, Hofmann and Rüsch (2017) outline that there is a lack of understanding of the concepts of Industry 4.0, and stress the importance of research being conducted to support companies in a practical manner, by developing concepts and frameworks related to different aspects of Industry 4.0. One of the key aspect towards Industry 4.0 according to Shaohua (2017), is the possibility of tracking movements and flows of material, machines, tools, people, forklifts etc. in real-time, which could enable digital communication between assets and the optimisation and full control of the workshop. In this domain Real-Time Location Systems (RTLS), which have the potential of collecting real-time data of the logistic flows have gained attention (Bin, et al., 2008).
Introduction

1.2 Problem description
Zang and Wu (2010) already highlighted about a decade ago, that companies expect immense benefits of the application of RTLS in their supply chain. Companies do however struggle with the questions of what a RTLS should specifically be used for and how it can complement their strategic set-up, which Gladysz and Santarek (2017) stress as a vital aspect in the consideration of the implementation of a RTLS. Zhu et al (2012) therefore propose in their outlook to future research that a model that objectively measures the value of location information would benefit practitioners. In relation to this, Cwikla et al. (2018) emphasize that real-time location information of assets and products can help companies in the optimization of their processes.

As already presented within the previous subchapter, lean production systems have become a commonly used approach for the optimization of processes. One of the main concepts within lean production systems, is Just In Time (JIT), about which Jadhav et al. (2015) state that it can bring major benefits, such as inventory cost-, space- or time reductions. They also point out that companies often struggle with sustaining the practical application of JIT.

Gladysz and Buczaki (2018) investigated how wireless technologies, like RTLS, could be applied to lean principles and found a strong correlation between RTLS and JIT, which implies that the challenges within JIT management could be counteracted by the application of RTLS. Within their outlook they point out that future research should be focused on how different lean methods could be assisted through wireless technologies like RTLS and suggest the necessity of support models that address the existing gap between theoretical concepts and practical implications of RTLS.

This thesis therefore explores how current research findings on potential benefits of RTLS could be applied within the management of JIT and material flows. This would assist practitioners with a deeper understanding of the potential and applicability of the technology.

1.3 Purpose and research questions
The purpose of this study was to investigate how the potentials of Real-Time Location Systems could be utilized within logistics management, by researching the positive impacts of Real-Time Location Systems on Just In Time management.

To fulfil this purpose two research questions have been formulated:
RQ1: What are the potential benefits of a Real-Time Location System in relation to its effect on Just In Time management?
RQ2: How could the logistics management at a manufacturing company conceptually be improved by utilizing the potentials of Real-Time Location Systems in correlation to Just In Time?
1.4 Delimitations and limitations
When researching logistic flows, the importance of a holistic perspective can be argued to be a central aspect to consider, in order to avoid sub-optimisations. However, as a delimitation for this study, two dimensions of logistics, one operational (the studied material flow) and one managerial (general challenges related to logistics management) have been selected. Even though several material flows are interconnected, these correlations are not investigated, nor evaluated.

Another delimitation of the thesis is related to the material flow that is studied to give an insight to the operational logistics management. Due to that the studied flow consists of both painted- and unpainted side panels, the flow is partly divided. This results in that the unpainted side panels are considered to enter the flow at the Sequencing Station, where the buffer of these articles are considered to be static and not investigated. The painted side panels are considered to enter the flow once Forklift 1 replenishes material to the Pallet Racking Storage (see chapter 4.3 and appendix 7.4).

Furthermore, the study is limited due to that it only presents conceptual suggestions on how the logistics management can be improved, but it does not investigate how large the efficiency improvements can be, nor does it consider economical aspects such as costs or return on investments. This delimitation is based on the purpose of the thesis, which was to investigate how the potential of RTLS could be utilized within logistics management. Based on this, the study also does not focus on how the differences within the technologies of RTLS affect the influence on logistics management, nor does it suggest a specific technology for implementation. Furthermore, the proposed framework in chapter 4.5 does not evaluate the impacts that related challenges might have on a RTLS. However, related challenges are discussed, and their importance are argued for in the discussion section.

1.5 Relevance of the thesis
1.5.1 Relevance to research
After having conducted a literature research, which focused at the impact and effects of wireless technologies (e.g. RTLS) on Lean, a key literature review by Gladysz and Buczaki was identified. Gladysz and Buczaki (2018) outline that there is a need within the academic community to research and develop support models for managers that can bridge the existing gap between theoretical concepts and practical implications. Considering this background, this thesis aims at providing the academic community with an evaluated framework of how a RTLS could improve identified challenges within JIT- and logistics management.

The results from this study will contribute to the academic community by increasing the understanding of how the potential of RTLS, can be considered and addressed in practical situations.
1.5.2 Relevance to practitioners

Scania CV AB has expressed concerns related to the risk of investing in a RTLS without first fully understanding its potential. Hence, this study will provide Scania CV AB and other companies in a similar situation, with concrete suggestions to what practical benefits a RTLS could bring. This will be possible by evaluating how identified challenges in material flows and logistics management could be counteracted by the potential of RTLS. The results from this study can allow Scania CV AB to further improve and develop its internal logistics.

1.6 Outline

The thesis is structured into five distinct main chapters:

Chapter 1 – Introduction: Presents a background to the field of studies, followed by a description of the problem phenomenon to be investigated. Within this chapter, purpose, research questions, delimitations and the relevance to research and practice are presented.

Chapter 2 – Theoretical background: This chapter consists of five main sub-chapters wherein an overview of the necessary literature and theoretical background for this study is provided. For this an insight into Industry 4.0, RTLS, Lean Manufacturing and Systems Theory is given, before the theoretical framework is presented, which answers the first research question.

Chapter 3 – Method and implementation: Discloses how the study was designed, conducted and which data collection techniques were used.

Chapter 4 – Findings and analysis: Within this chapter the findings regarding the general logistics management at the case company, as well as the studied flow are presented. In the end of the chapter the findings are summarized, analysed and categorized.

Chapter 5 – Discussion and conclusions: Within this section, the academic and practical implications are discussed as well as a discussion of the fulfilment of the study’s purpose and limitations. The chapter also consists of discussions related to the study’s reliability and validity. The chapter ends with suggestions for further research.
2 Theoretical background

The theoretical background is a main chapter for the study. Within the chapter a background to Industry 4.0 is given, followed by a deeper explanation of RTLS and Lean manufacturing. This provides the necessary background of the two central areas of the thesis. The chapter then focuses on RTLS and its potential in relation to JIT management, which is compiled to a theoretical framework within the last subchapter.

2.1 Industry 4.0

The increased focus on digitalization over the last years has brought with it, what is commonly perceived as the fourth industrial revolution, or Industry 4.0. The term Industry 4.0 was first coined at the Hanover Trade Fair in 2011, where it was presented as part of Germany’s high tech strategy to brace its industry for the production requirements of the future (Hofmann & Rüsch, 2017). Because Hofmann and Rüsch (2017) are of the opinion that Industry 4.0 has become a buzzword, that is in need of a deeper conceptual understanding, they have created the following definition of the term:

"the Fourth Industrial Revolution can be best described as a shift in the manufacturing logic towards an increasingly decentralised, self-regulating approach of value creation, enabled by concepts and technologies such as CPS, IoT, IoS, cloud computing or additive manufacturing and smart factories, so as to help companies meet future production requirements."

This definition is built upon the four key components Hermann et al. (2016) outline:

1. **Cyber Physical Systems (CPS)**
   Hofmann and Rüsch (2017) describe CPS as systems that interconnect the physical and virtual world with sensors, actuators, control processing units or other communication devices. This allows computers or networks to monitor or even control physical processes.

2. **Internet of Things (IoT)**
   The term IoT has been described by Hofmann and Rüsch (2017) as a world wherein all things/products can become “smart things” by having an incorporated small computer, which is connected to the Internet.

3. **Internet of Services (IoS)**
   The term IoS, similarly to the IoT, summarizes services that “are made easily available through web technologies, allowing companies and private users to combine, create and offer new kind of value-added services” (Hofmann & Rüsch, 2017)

4. **Smart Factory**
   Smart Factories can be understood as the integration of CPS, IoT and IoS, to build a factory that is aware of its context and that helps people and machines in their tasks (Hermann, et al., 2016). According to Hofmann and Rüsch (2017) this allows for a very flexible and individualized mass production, which is also cost efficient, because easily identifiable and localizable products move independently through the production process.
Theoretical background

Cwikla et al. (2018) furthermore outline nine main technological advances that build the basis of Industry 4.0 as:

1. Big Data analytics,
2. Autonomous robots,
3. Modelling and simulation,
4. Horizontal and vertical system integration,
5. The Industrial Internet of Things,
6. Cybersecurity,
7. The cloud,
8. Additive manufacturing

In front of the criticism of Industry 4.0, as lacking a commonly accepted understanding, it can be argued that the concept Industry 4.0 is less off an in itself coherent concept. Instead, it can be viewed as an umbrella term that describes different approaches towards taking production management and the industrial sector in general to the next level, by applying digitalization and the technical advances of the 21st century. One of the consistently argued standpoints however, is that one of the prerequisites of Industry 4.0 is the localization of goods and assets throughout the entire supply chain (e.g. Hofmann & Rüsch, 2017; Cwikla, et al., 2018), which is one of the key aspects and functionalities of a RTLS, since it allows companies to digitally track and trace their assets in real-time.

2.2 Real-Time Location System

The International Organization for Standardization (ISO) defines a Real-Time Location System (RTLS) as:

“wireless systems with the ability to locate the position of an item anywhere in a defined space (local/campus, wide area/regional, global) at a point in time that is, or is close to, real time.” (International Organization for Standardization, 2014)

The definition above implies that any system that generates track- and trace data in close to real-time, can be viewed as a RTLS. Hence, what is to be considered as a RTLS, is up to the user’s perspective of what is real-time accessibility of information to them. Gladysz and Santarek (2017) point out that RTLS translates to most practitioners as an “indoor GPS system”, with the main purpose of locating objects within relative coordinates. While this is the foremost purpose of RTLS, Budak and Ustundag (2015) furthermore call attention to the possibility of collecting and monitoring further data, like speed, temperature, humidity or other pre-defined information about the tracked object. This depends upon the possibility of interconnecting the applied technology to sensors that are able to monitor the physical condition of the located objects.

For this thesis, RTLS is to be understood as any system that allows the user to locate its products or assets within specific coordinates in real-time. Thus, within this thesis, literature describing RFID being used for real-time purposes is also taken into consideration.
Theoretical background

Throughout the following subchapters a common understanding of Real-Time Location Systems is issued. For this, an insight into the general functionality of RTLS will be provided, followed up by an introduction into the most commonly used technologies and an overview of possible application areas.

2.2.1 The general infrastructure and functionality of RTLS

There are several different ways of distinguishing between RTLS, but the most common way within the literature is to divide between indoor and outdoor tracking technologies. This differentiation is also applied within the following subchapter (2.2.2) to organise the different technologies. On top of this, Cwikla et al. (2018) created a classification of indoor RTLS, wherein they differentiate between the categories of active and passive systems. Passive systems locate an object without having it equipped with an electronic device e.g. through video analysis or the variance of a measured signal. In an active system on the other hand the objects are equipped with a device that “actively communicates” its position.

While the exact set-up of an active system can differ dependent upon the used technology, the general infrastructure (see Figure 1) can be summarized by its four main components (Gladysz & Santarek, 2017):

![General RTLS Infrastructure based on Gladysz & Santarek (2017)](image)

(1) Tags

The electronic device attached to the to-be-located object is usually referred to as a “tag”. It consists of a chip, that stores and processes information about the focal object and an antenna that transmits and receives that information to the locating device (2) (Zhu, et al., 2012). Zhu et al (2012) amongst others furthermore differentiate the tags by whether they have their own power source or not. Active tags use an integrated battery, while passive tags receive their energy from the radio frequency generated from the locating devices (2), which results in passive tags only working in proximity to the locating devices (2).
(2) **Locating Devices**  
The locating devices are generally fixed in a specific and known position and create the link between the tags (1) and the location engine (3) (Gladysz & Santarek, 2017).

(3) **Location Engine (server)**  
The Location Engine processes the data collected by the locating devices (2) to determine the position of the tags (1), attached to the focal object. For this, several different measurement techniques can be used, which are presented later within this subchapter.

(4) **User Applications and Interfaces**  
Dependent upon the purpose and the use of the RTLS, the location engine can be connected to different user applications or existing systems like ERPs to allow the user to draw on the benefits of knowing the location of the focal object. Dardari et al. (2015) furthermore bring into the discussion the difference between localization, tracking and navigation. According to them, localization, which describes the identification of the location of an object within relative coordinates, is the most basic objective of a RTLS. Tracking, on the other hand, is described as putting those independent location estimates into sequence, which also allows estimates of the velocity and acceleration of the tracked object. Lastly, navigation uses past position estimates to control the course and current position of an object.

The most basic version of localizing an object is described by Specter (2009) as reading a tag as it passes fixed choke points e.g. a door, an opening or a point on a conveyor belt. While this version only shows where an object has been and not necessarily its exact location in real-time, it can still be defined as a RTLS if it is only necessary to limit the area where the object is located (e.g. WIP Storage).

For more advanced systems, that define the actual coordinates of an object/tag in real-time, Dardari et al. (2015) created a framework by categorizing three different ways of processing the measured data of the RTLS. These are:

1) **Geometric-related measurements**  
This technique of localizing a tag/object, uses triangulation of the received signal of at least two locating devices to clearly define the location of the object within relative coordinates. Examples for geometric related measurements are RSS - Received Signal Strength, TDOA - Time Difference of Arrival, AOA - Angle of Arrival and PDOA - Phase difference of Arrival (Dardari, et al., 2015). Cwikla, et al. (2018) also mention the measurement technique DOA – Direction of arrival.

2) **Position-related measurements**  
According to Dardari et al. (2015) position related measurements use “signals of opportunity” that are already deployed within the infrastructure, like a Wi-Fi-network. There is however usually too much interference from other objects,
which is why these measurements are often supplemented by other measurements. Other signals of opportunity mentioned are ambient light/audio, ultrasound and video signals.

3) **Self-measurement of inertial devices**

The self-measurement of inertial devices does not require any locating devices, but instead uses sensors directly on the device, which allow for the measurement of the initial position, velocity, and orientation of the device to locate its position, as is often used within automated guided vehicles.

2.2.2 Technologies and selection criteria

In this subchapter the most commonly mentioned technologies from the literature are presented. Furthermore, an insight into the criteria, that companies can use when deciding upon the implementation of a specific technology, is given.

2.2.2.1. **Overview of Technologies**

The most commonly used RTLS technologies for indoor RTLS in a predefined space are:

- **Radio Frequency Identification (RFID)**
  RFID has become so common as a RTLS technology, that within the research community the terms RFID and RTLS are often used synonymously (e.g. Specter, 2009; Zang & Wu, 2010). Curran et al. (2011) however point out that the greater part of RFID applications only use the most basic version of RTLS, which allows for the localization of an object in a specific zone, rather than an actual real-time tracking of the object. RFID uses radio frequencies to locate the objects close to the receivers and has the advantage of not needing a line of sight to the objects (Bin, et al., 2008). The accuracy and cost of an RFID-RTLS is dependent on the amount of tags and receivers needed to cover the required area (Dardari, et al., 2015).

- **Ultra-Wide Band (UWB)**
  For UWB-RTLS, active tags transmit radio waves at a high bandwidth, which allows for an accuracy of down to a decimetre (Specter, 2009). The disadvantage of UWB is also that there can be problems in detecting objects without a line of sight (Dardari, et al., 2015).

- **Wi-Fi**
  Wi-Fi-RTLS use Wi-Fi transmission signals to locate tags or mobile devices that are equipped with a Wi-Fi module (Curran, et al., 2011). It has a comparatively low accuracy of 1-5 metres, but has the advantage of being very cost-efficient, because a lot of the already existing infrastructure can be used. There might also be the disadvantage of interfering signals, which is why for this RTLS a “fingerprinting”-database is required. (Dardari, et al., 2015)

- **Zigbee (based on IEEE 802.15.4)**
  Zigbee operates via a self-healing mesh network that passes data from one node to another through multiple paths (Malik, 2009). It has a rather low accuracy of 1-10 meters, but also comes at a rather low cost (Dardari, et al., 2015).
Theoretical background

- **Bluetooth (BT) / Bluetooth Low Energy (BT-LE)**
  The use of Bluetooth technology for RTLS is similar to RFID technology, in that its accuracy and cost is dependent upon the number of receivers and tags used and that it does not require a line of sight (Dardari, et al., 2015) Over the last few years, a new technology of Bluetooth Low Energy (BT-LE) has become more popular for the use within RTLS. Apart from lower costs and an extended coverage in comparison to traditional Bluetooth, one of the advantages of BT-LE is that the battery of the active tags can last over long periods of time. In an RTLS application, this means that there will be less maintenance required for charging the tags (Pancham, et al., 2017).

- **Infrared (IR)**
  According to Bin et al. (2008) IR is a rather low-cost solution with a good usability, by having active tags send out an infrared signal. It has a low penetrability, making it suitable for in-room localization, but it has a rather low precision and is disturbed easily.

- **Passive Systems**
  As previously mentioned, examples for passive RTLS are ultrasound, some UWB applications and very basic systems like physical contact or video analysis (Cwikla, et al., 2018).

For outdoor RTLS, the following technologies are most commonly discussed:

- **Global Positioning System (GPS)**
  GPS uses triangulation of satellite data, which allows the system to locate objects outdoors (Specter, 2009). It therefore has the advantage of a global coverage down to an accuracy of several meters. But the infrastructure is rather expensive, and it cannot be used for indoor localization, because it requires a line of sight (Dardari, et al., 2015).

- **Cellular**
  Cellular networks also allow an outdoor tracking on a country wide basis on a similar accuracy as GPS. Due to the relatively low accuracy, they are also unsuitable for indoor tracking and they furthermore require a synchronization of the base stations (Dardari, et al., 2015).

Cwikla et al. (2018) also point out that Hybrid Systems, which combine two or more technologies, improve the accuracy of the RTLS and can help with some of the most common problems in RTLS like signal interference, line of sight or a high number of objects. This is furthermore underpinned by the evaluation of different technologies by Budak and Ustundag (2015) and the statement by Dardari et al. (2015) that no technology is currently able to perform satisfactory in regard to cost, accuracy and coverage in all environments, which makes them conclude that a mix of technologies is required.

**2.2.2.2. Selection Criteria**

For the selection of a RTLS technology, many authors point out that the most vital concern is to take the purpose, usage and environment of the RTLS into consideration (e.g. Budak & Ustundag, 2015; Gladysz & Santarek, 2017 and Curran, et al., 2011). Cwikla et al. (2018) furthermore state that the selection should be based upon the required accuracy, speed and cost as well as the need to pay attention to the environment of the RTLS. Pancham et al. (2017) also identified cost and accuracy, as well as energy
Theoretical background

consumption, size, detection range and scalability as important criteria for the selection of a RTLS technology.

Budak and Ustundag (2015) additionally created a multi-level decision making model (see Figure 2), that does not only consider the technical possibilities, but also the organizational environment for the RTLS. Within their model different technologies can be evaluated against one another by assessing them for each selection criteria alongside a five-step scale (very poor to very good), which are then factored into the overall evaluation of the technology with different weights.

Figure 2 - Multilevel selection criteria for RTLS based on Budak and Ustundag (2015)

2.2.3 Applications for Real-Time Location Systems

RTLS has found application areas in many different industries. Gladysz and Buczaki (2018) point out in a literature review that there have been numerous articles written about the application of RTLS in healthcare, agriculture, home and building automation as well as public safety. Apart from those, Zhu et al. (2012) also give examples of the applications of RFID in the apparel and consumer goods retail industry, the food and restaurant industry, in travel and tourism industries, as well as library applications, the military and the paper industry. Cwikla et al. (2018) furthermore add government applications, security, conference guides and general location based network access to the list.

As large as the variety of industries are, that have been using RTLS, as various are the tracked items. For example, Cwikla et al. (2018) state that within the manufacturing industry the following objects are the main focus for tracking or localization:

- Mobile assets
- Workers
- Products
- Materials
- Key components
- Means of transportation (e.g. forklifts)
- Containers (e.g. pallets).
Theoretical background

Based on the wide range of different application areas, the benefits of RTLS are numerous and often differ, dependent upon the function of the RTLS. Gladysz and Santarek (2017) summarize the main advantages within the area of production and logistics as:

- Controlling and reducing inventory,
- Increasing the cooperation within a supply chain
- Fighting maritime piracy
- Assets tracking in container terminals
- Improving mobile (transportation) assets
- Increasing the utilization in manufacturing
- Tracking of assets on a shop floor
- Supporting decision making systems and improvements in maintenance
- Component tracking
- Collision avoidance
- Offshore logistics

Zhu et al. (2012) furthermore point out that RTLS can cut ordering lead time as well as improving inventory control, by increasing data accuracy, decreasing cost and avoiding stock-outs. Gladysz et al. (2018) conducted a case study investigating the application of RTLS to increase production efficiency by enabling a dynamic spaghetti diagram. Further examples of the use of RTLS for Lean initiatives will be presented within chapter 2.4.

2.2.4 Challenges related to Real-Time Location Systems

The main risks and challenges in regards to RTLS can be summarized as being related to: (1) organizational culture and technology challenges; (2) costs, risks and technical competence; (3) cyber security; (4) Battery Capacity and (5) Environment and surrounding challenges:

(1) Organizational culture & technology challenges

Dai et al. (2012) identified two main challenging factors regarding the implementation of an RFID:

Challenges related to people: It has been found that some workshop individuals were reluctant to the changes and there was a need to educate the employees, for them to become skilled within the new technology.

Challenges related to the technology: They found that there were three main challenges with the technology of a RFID, (1) poor storage capacity of the tags, (2) interference and slow response when several tags were used simultaneously and (3) poor processing time when a lot of data was transmitted.

(2) Costs, risks and technical competence

Huang et al. (2010) found that the implementation of RFID faces three main challenges, they refer to this as the Three High Problems. The Three High Problems are high cost, high risk and high requirement of technical skills. To overcome these challenges, Huang et al (2010) suggest for the supply chain to partner up and create an alliance and thus share costs, risk and technical competences. This would allow all actors of the chain to reap the benefits of the system, without separately investing in their own system.
They also outline that common benefits related to the sharing of investments are optimized logistic processes, increased transparency and information sharing, improved shop floor planning and scheduling, a limited risk of the bullwhip effect and improved JIT flow from the suppliers.

(3) Cyber Security
Hinai and Singh (2017) outlines that wireless systems, e.g. RTLS, increase the exposure for cyber security attacks on the system. They categorized the attacks in two main areas; (1) passive attacks, these are the attacks where the intruder enters the digital space and monitors the network to e.g. withdraw valuable information, (2) active attacks on the other hand are defined as the intruder tempering with the information and/or takes down the system. They also outline three distinct layers within the wireless system where attacks can occur; (1) perception layer, the layer where data is being collected from the tags, (2) network layer, where the data is being transmitted within the system and (3) application layer, they layer where the software controls the data and its confidentiality.

(4) Battery Capacity
Lohan and Singh (2017) stresses the importance of battery capacity and battery life time for wireless communication system. They explain that this could be considered as one of the most important aspect within the object management, due to that wireless systems that are using active tags, consisting of e.g. sensors and identification technology, consumes a lot of energy to function and be reliable. This is important to maintain a stable and reliable use of the system.

(5) Environment and surrounding challenges:
Fisher and Monahan (2012) assessed the use and implementation of a RTLS in a hospital setting. They outline that the functionality of an RTLS is strongly affected by the environment and surrounding in which it is installed and operates in. This is due to that certain material might reflect or reject the signals from the tags, complex structures of the building and challenging flows to manage. These finds allowed the researchers to conclude that the environment in which the RTLS is considered to be installed in should individually be evaluated, due to the strong negative effect it has on the system.

2.3 Lean Manufacturing
Lean Manufacturing has been one of the most vital concepts within the manufacturing industry throughout the last few decades. The term Lean has become a buzzword within the industry since Womack et al (1990) publizised the book “the machine that changed the world”, but it was first coined by Krafcik’s (1988) description of the Toyota Production System (Samuel, et al., 2015). The Lean Enterprise Institute (2008) define Lean Production as:

“A business system for organizing and managing product development, operations, suppliers, and customer relations that requires less human effort, less space, less capital, less material, and less time to make products with fewer defects to precise customer desires, compared with the previous system of mass production.”
A method to incorporate this vision is through the 5 lean thinking principles by Womack & Jones (Womack & Jones, 2003):

1. Define what *Value* is through the standpoint of the end customer.
2. Identify the *Value Stream* and eliminate all the tasks that do not create value.
3. Create a *Flow* in the value stream, instead of dividing the value creation into functions and departments, which reduces the time
4. **Pull** – produce what the customer wants when he wants it
5. Repeat steps 1-4 to achieve **Perfection**

### 2.3.1 The Toyota Production System (TPS)

As mentioned earlier, Lean is based upon the Toyota Production System (TPS) which is accredited to the leadership of Taiichi Ohno at Toyota after the Second World War, when Japanese companies were struggling with a scarcity of resources and severe local competition. The TPS is often summarized visually as a house (see Figure 3) with two pillars representing its two main concepts JIT and Jidoka, which stand on a basis of stability and engages people to level the production flow (Heijunka), standardize work procedures and continuously improve (Kaizen) in order to reach the goal of the best possible quality at the lowest possible cost within the shortest possible lead time (The Lean Enterprise Institute, 2008).

![Figure 3 - The TPS House based on The Lean Enterprise Institute (2008)](image)

JIT, which is related to the flow of production and is presented in more detail in sub-chapter 2.3.3, and Jidoka are therefore the two main concepts within the TPS. Jidoka is often translated with the term autonomation, which Womack and Jones (2003) define as:

“*transferring human intelligence to automated machinery so machines are able to detect the production of a single defective part and immediately stop themselves while asking for help*”

It is therefore a concept to ensure problems and defects are responded to as early as possible and it is most frequently related to Lean tools like Andon, Poka Yoke and Visual Management (The Lean Enterprise Institute, 2008).
Theoretical background

2.3.2 Waste

The elimination of waste or muda, as it is called within the TPS, is the core idea behind Lean management. The idea is to identify all tasks within a process as either:

1. Value adding (from the perspective of the end-customer)
2. Non-value adding, but necessary

Within Lean Management, the lead time and cost are decreased by eliminating all tasks that are waste (3) and by minimizing the non-value adding, but necessary (2) tasks (Myerson, 2012).

For this Taiichi Ohno identified seven types of waste, which were supplemented by an eights type from Womack and Jones (2003):

1) **Overproduction**
   Producing more than the customer demand

2) **Waiting**
   Operators or machines having to wait for the machine to finish, parts to arrive, etc.

3) **Conveyance**
   Moving parts/products unnecessarily or over an unnecessary distance

4) **Processing**
   Performing the wrong - or more processing steps than necessary

5) **Inventory**
   Having more inventory of raw material or work-in-progress (WIP) than necessary to maintain the production flow

6) **Motion**
   Straining or unnecessary movements by the operator

7) **Correction/ Defects**
   Scrapping or having to rework products, also includes inspection

8.1) **Design of goods or services that do not fulfill the customers’ needs**
   Putting effort into the design of something the customer does not need or want

The eight waste by Womack and Jones is usually not mentioned within the common Lean literature, instead a different eight waste is often referred to (e.g. Myerson, 2012):

8.2) **Unused employee potential**
   Not utilizing employees’ creativity, skills and knowledge.

2.3.3 Just In Time

JIT is a main concept within Lean production management and it has been described as the most powerful method for inventory management (Jadhav, et al., 2015). Khojasteh (2016) provides the following definition of JIT:

“**JIT is a set of principles, tools, and techniques that allows a company to produce and deliver products in small quantities, with short lead times to meet specific customer needs. It is an inventory strategy to increase efficiency and decrease work-in-process (WIP) inventory, thereby reducing inventory costs.**”

The Lean Enterprise Institute (2008) states that the basis of JIT is a levelled production flow (Heijunka) and refers to the pull system, takt time and continuous flow as its main elements:
Theoretical background

- **The Pull System:**
  The pull system reduces overproduction and WIP inventory, by only performing upstream activities when a need has been signaled from a downstream activity (The Lean Enterprise Institute, 2008). Khojasteh (2016) explains three main control systems to ensure pull-production, that can also be used as hybrid systems:
  
  (1) **Kanban**
  Within a Kanban system the production of each station is triggered by the demand of the station directly after it, by the upstream station sending a signal (or Kanban card) to the previous station that a part has been used and therefore needs to be replenished (see Figure 4).

  ![Figure 4 - KANBAN Control of a serial production line based on Khojasteh (2016)](image)

  (2) **CONWIP (Constant Work-in-Progress)**
  Within a CONWIP System, the WIP inventory is controlled by only issuing the release of a new part, when an existing job is finished and exits the line (see Figure 5).

  ![Figure 5 - CONWIP Control of a serial production line based on Khojasteh (2016)](image)

  (3) **Base-stock**
  Within base-stock system the WIP is managed by putting a maximum on the planned inventory after each work station. For this all stations are informed individually of the production demand, which means that they build up inventory, if an upstream operation breaks down (see Figure 6).

  ![Figure 6 - Basestock Control of a serial production line based on Khojasteh (2016)](image)

- **Takt Time:**
  The Takt time of a production line is calculated by dividing the available production time per day by the customer demand per day. Because it is based on the actual customer demand it is a powerful tool to avoid e.g. overproduction.
Within JIT production the Takt time defines the pace of the production line, which in turn specifies the cycle time of the different work station (Bertoncelj & Kavcic, 2012). It therefore helps production managers in the improvement and the balancing of the production flow, since operations are identified as bottlenecks if their process time is longer than the calculated Takt.

- **Continuous Flow:**
  The essential goal of continuous flow would be a one-piece flow, which is translated in practice into items (or small and consistent batches of items) being produced and moved through the production line as continuously as possible. It is based upon the Flow Production Henry Ford introduced in his car factory in the beginning of the 20th century, which was relying upon the layout of the process steps being in the right sequence and stable cycle times across the different workstations (The Lean Enterprise Institute, 2008). This allowed production parts to move smoothly and quickly through the production line. Within JIT, the flow production is further enhanced by using the Takt of customer demand as cycle times and by minimizing batch sizes, which in turn reduces waiting times and WIP inventory.

Within the literature JIT is most often associated with the reduction of WIP Inventory and the reduction of lead time (e.g. Khojasteh, 2016; Jadhav et al., 2015). Khojasteh (2016) points out two main aspects of inventory that support the importance of inventory reduction within JIT management:

1) High inventory levels have a negative effect on the cash flow, since more capital is tied up in assets. Hence, it also has a negative effect upon the price competitiveness of a company.

2) High Inventory levels hide problems within the production process like machine breakdowns, long-set up times, inefficient layouts, poor product quality, unreliable suppliers etc. Hence, by having high WIP inventory, insurances for abnormal situations are built into the process. The imagery often used to illustrate this, is a boat (the production) floating on a sea of inventory over a ground of rocks (covered issues). The more the inventory level is decreased, the more root causes of problems are uncovered, which provides the basis for long-term solutions to the problems.

JIT therefore does not just aim at the reduction of waste in the form of Inventory, but Overproduction, Waiting, Conveyance, Processing and Motion waste is often also reduced, because JIT can uncover several wastes within the production flow.

Jadhav et al. (2015) identified the challenges involved in JIT production, which he summarizes as 12 main barriers:

1) Missing management support
2) Insufficient training/education of employees
3) Financial constraints
4) Resistance of employees
5) Lack of sustaining the made changes
6) Poor planning/layout of the facilities
7) Differences in organizational culture
8) Lack of a thorough planning system
9) Insufficient information flow
10) Conflicts between different departments/functions
11) Lack of flexibility to react to changing markets
12) Insufficient forecasting
A method frequently used in the analysis of production flows in order to implement or evaluate a JIT flow is Value Stream Mapping (VSM). Hurt, et al. (2015) define it as:

“a tool that allows visualization of transport, material and information flow throughout all processes in the supply chain or a part of it.”

In general, a Value Stream Analysis consist of three parts (The Lean Enterprise Institute, 2008):

1. Mapping the current state, including all the activities and their times in the production flow and the corresponding information flow, whilst also differentiating value-adding or non-value-adding times
2. Creating an ideal state, of how the production - and information flow should be if there were no constraints
3. Compiling a future state, which tries to apply most of the ideas generated in the ideal state, while taking cost, space and other constraints into consideration.

Since VSM relies on standardized visual tools and key icons (Hurt, et al., 2015), that have become well-known within the industry, the method can simplify the communication of material and process flows amongst practitioners.

Lugert and Winkler (2019) point out that a disadvantage of VSM is its static character, since the map relies on data collected at one point in time, and suggest that the move towards digitalization in today’s industries could bridge that disadvantage.

2.4 System theory

Zelbst et al. (2014) explain that within an organization it is crucial to view the company or organization as an interconnected system, consisting of several sub-systems. To achieve a competitive edge, all functions and activities need to be well planned and coordinated. They outline that a key aspect within the system theory is transparency and information sharing. Hull (2011) also underlines that within the system theory perspective, a slight change within one part of the system, exponentially increases the pressure on other sub-systems to react to the change. An organization’s ability to successfully improve its processes and routines, is closely connected to its ability to share information within the system.

2.5 Correlations between RTLS and Lean Manufacturing

In recent years, the focus has been directed towards investigating how wireless technologies, such as RTLS, can assist companies to further improve within the Lean Production System. Gladysz and Buczaki (2018) reviewed research from 2008-2017 to investigate the correlations between wireless technologies and Lean principles and tools. They conclude that there is a strong support of wireless technologies to positively impact the Lean concepts of JIT.

Based on the definition of RTLS (see chapter 2.2), and that RFID in literature often is used synonymously with RTLS (e.g. Specter, 2009; Zang & Wu, 2010), this thesis build on the above argued correlation between RTLS and JIT and thus uses the literature review by Gladysz and Buczaki (2018) as the basis of academic examples for the creation of a framework in chapter 4.5.
Presented below are the main findings and conclusions of 13 selected articles that have investigated the effects of wireless technologies on JIT:

1. **Powell and Skjelstad (2012)** conducted a study to explore the role of RFID in a Lean driven manufacturing supply chain context. They performed two case studies within two different companies in Norway. At the first company they found that the implementation of RFID greatly increased material- and flow control, allowed for track- and tracing, rationalized shipping and receiving processes. Hence, the implementation of RFID increased transparency and visualization in real-time, which allowed for improved JIT flows. The second company gave similar results, but they also found that the JIT flow was improved by using the RFID system to improve the efficiency of the kitting and sequencing of material, as well as to minimize the setup time for machines considered to be bottlenecks. This allowed to company to shorten lead times and improve their delivery accuracy.

In summary, Powell and Skjelstad (2012) determine that the main potential and benefit of an RFID system for a Lean enterprise lies within the improved communication, which originates from the ability to trace and track products, allowing companies to increase stock- and material flow control.

2. **Haddud et al. (2015)** studied possible effects on Leans seven wastes by researching conceptual implications of implementing a RFID system. The study involved seven manufacturing industries in the USA and had a qualitative approach where key individuals with expertise of RFID and Lean manufacturing responded to an online questionnaire. The results show that there is strong support for the hypothesis of RFID minimizing Leans seven wastes. Haddud et al. (2015) conclude that RFID systems have the potential of increasing the manufacturing control by improved JIT flows and eliminating waiting times for material.

3. **Rafique et al. (2016)** conducted a literature review of articles published, in the time period 1988-2015, to explore how RFID could be used as an enabler to overcome Lean manufacturing barriers. The study covered 139 articles, of which 120 were from well recognized scientific journals. They argue that even though Lean is considered to be one of the best methods to achieve organizational efficiency, there are several implementation issues that create unwanted barriers. In their research, they divided the identified barriers into three distinct categories, managerial- (culture, management commitment, employee attitude, employee relations), operational- (customer relations, inventory, lead times) and financial regime (constrains of resources and lack of financial means). When they relate the three category-barriers to the academic findings of RFID, they outline that the key applications of real-time traceability and on-demand information access will improve the inventory- and production management and shorten lead times. These functionalities bridge barriers both within the operational- and managerial regime. The RFID system also allows for a real-time tracking of assets, which have a
Theoretical background

great impact on operational efficiency, and to aid managers, by providing them with the necessary information to improve the employee management. They conclude that there are several benefits to implementing a RFID system, which in turn also affect the culture and atmosphere in the workshop. They also argue that since several positive effects can be expected and a more efficient organization can be achieved, the long-term benefits will decrease the challenges related to the financial regime.

4. Chongwatpol and Sharda (2013) explored if increased visibility of information, generated from a RFID system, could complement organizational struggles to minimize Leans seven wastes. They conclude that the key functionality of increased accessibility of tracking and tracing has a great positive affect on Lean wastes. They outline that such a system will assist companies in the work of identifying bottlenecks and in increasing the control of products and components within the plant.

5. Patti and Narsing (2011) researched the correlation between RFID and Lean Manufacturing, in regard to how RFID affected identification, Kanban and tracking of products and components. They found that; (1) RFID can greatly rationalize the identification of goods, by allowing the tags to automatically transfer information of the products instead of a manual handling of e.g. scanning barcodes. (2) RFID can enable e-Kanbans that reduces manual work by limiting the need of physically searches for Kanban cards. The e-Kanbans instead automatically send a signal to the picker, once a replenishment of material is required. (3) The ability to track and trace material in real-time within the plant assists managers to improve material- and logistic flows, which ensure that material is at the right place, in the right time and in the right amount (JIT and JIS). They also determine that there is a great potential in the scalability of RFID Systems, since new applications and up-scaling only requires marginal investments, once the costly system infrastructure has been installed.

6. Su et al. (2009) studied how a RFID system could be used as a tool to enable a more rational JIT flow by implementing e-Kanbans. They found that an e-Kanban system, based on RFID, could have a great impact on the velocity of the circulation of the Kanban cards within the plant and reduce the risk of human errors and mistakes. They conclude that a RFID system has a great potential of increasing the information system for the focal company, by enriching the amount of data collected and allowing managers to further improve production and logistics, through real-time tracking and information access.

7. Kouri et al. (2008) defined crucial factors that should be considered when planning to implement a RFID system to achieve a better JIT flow by e-Kanbans. They outline that e-Kanbans will increase the visibility within the production system, which is considered to be the foundation of JIT, where e.g. an RFID could give support for continues improvements. The outcome of their study is that a key factor for companies to consider
is to build into the system a support-feature for continues improvements in order to embrace the full potential of the system in a JIT flow.

8. **Huang et al. (2010)** suggest for the supply chains to partner up and create an alliance and thus share costs, risk and technical competences. This would allow all actors of the chain to reap the benefits of the system without separately investing in their own system. They also outline that common benefits related to the sharing of investments are optimized logistic processes, increased transparency and information sharing, improved shop floor planning and scheduling, a limited risk of the bullwhip effect and improved JIT flow from the suppliers.

9. **Dai et al. (2012)** studied the implementation of a RFID system at a supplier for the automotive industry in China. After the implementation, they listed the following success factors of the project.

   - **Top management support:** The implementation of RFID was considered a cornerstone of the information sharing system of the company by the CEO. This created a positive and motivating atmosphere for all the managers to embrace the change with a determination to succeed.
   - **Business process reengineering:** The company dedicated a lot of time and resources to the examination of the current state and to define the future state. This allowed the project to identify barriers and develop action plans to overcome challenges.
   - **Bottom-up information strategy:** Allowing information from the shop floor to be quickly and easily accessible when needed, was the foundation for the company to be able to make the correct decisions.
   - **Collaborative teamwork:** During the project, people worked together in the same location. This allowed for knowledge- and information sharing throughout the process. To increase the collaboration between individuals further, several workshop and seminars were also held.

Dai et al. (2012) outline that since the first implementation there have been several upgrades to the installation, for example an implementation of an enterprise resource planning (ERP) system that allows the company to source and plan in real-time.

10. **Zelbst et al. (2014)** researched how the utilization of a RFID system could impact JIT, TQM and the operational performances of manufacturing companies. They especially focused their research on the value of information sharing. They found that a crucial factor to embrace the full potential of RFID is to have established information and data sharing capabilities, e.g. ERP systems. They conclude that the combination of RFID with information sharing systems will allow companies to become leaner by more effectively eliminating waste related to material, WIP and inventories. This will in turn have a positive effect on customer satisfaction and delivery responsiveness.
11. **Chen and Tu (2009)** constructed and tested a framework for the implementation of RFID, to monitor, coordinate and control dynamic flows internally within a production company. The framework was based on software entities, *agents*, that constantly monitored the data received by the RFID system. The software then analyzed the data and selected appropriate actions to take, based on specific signals that were triggered within the system. They integrated e-Kanbans into the system which allowed the company to become more agile and greatly reduced wastes related to material storage and transportation at the production floor. They conclude that real-time monitoring technologies are a prerequisite for companies that are striving to gain competitive edges, in becoming more agile and efficient. One of the key findings of the study was that real-time information accessibility of products, parts and flows allowed the company to respond faster to events at the production lines and provided managers the opportunity to make more informed decisions when improving production layouts.

12. **Li and Fan (2008)** studied how improved online and digital information sharing, throughout the supply chain, could affect the JIT principle for *Third Party Logistics* (3PL) distribution systems. They discussed how real-time tracking and traceability of material and load carriers, could provide the 3PL with key information that could ultimately rationalize the planning of transportation and the logistic flows. This would benefit both suppliers and customers, by having less tied up assets in material being stored or transported.

13. **Tabanli and Ertay (2013)** researched the value of RFID-based e-Kanbans by studying the implementation of the system at a supplier for the automotive industry. In their study, they consider costs related to the hardware, software and service. The benefits of the system, they categorized into two categories: (1) decrease of cost and (2) increase in customer satisfaction. After analyzing the costs and benefits of the RFID system, they found that the company would see a return on investments within 21 months. They conclude that the initial implementation of the system is the most expensive cost in the project. Once the system has been implemented, it will not be as costly to scale up the system, since a major part of the infrastructure is already installed. They also outline that in relation to a traditional Kanban system, the e-Kanban system does not only eliminate the loss of Kanban cards, but also increases the visibility of the inventory, which allowed the company to withdraw correct data from the system.
3 Method and implementation

This chapter of the thesis first explains the structural approach that was used to answer the research questions. It then gives an insight to the case company, before explaining and justifying the selected research method. The last sections of the chapter are dedicated towards presenting the data collection techniques used for the study.

3.1 Connection between research questions and method

The purpose of this study was two dimensional: First, to identify the potential of RTLS to positively impact JIT management, and second to explore how these potentials could be utilized within logistics management.

To fulfil these two dimension of the purpose, a structured approach for the study was designed (please see Figure 7). The project was divided into six main stages (see 1-6), where each of the stages provided an essential contribution to answering the proposed research questions:

(1) Creation of a theoretical framework:
Literature and academic articles were collected from several sources to provide the study with a necessary theoretical background to create a conceptual framework for evaluating RTLS potential and possibilities in a JIT flow. The framework is presented in Table 12, chapter 4.5.

(2) Identification of general logistics challenges and a suitable flow
Information on the general logistics management at the focal company was collected by conducting six exploratory interviews with key personnel at the case company. These interviews were also used to identify a suitable material flow for the study of the operational logistics management at the case company.

(3) Investigation of the material flow
The data collection techniques selected to study the flow were observations - which also included time studies, interviews and reviewing internal documents.

(4) Identification of operational logistics challenges
The operational logistics challenges at the case company were identified by analysing the studied flow and categorizing the findings.

(5) Additional data collection of the logistics challenges
To increase the reliability of the data, key personnel at the company were invited to a focus group to discuss strengths and weaknesses within the company’s logistics management and material flows.

(6) Evaluation of the potentials of RTLS
The analysed findings of the general logistics challenges and the studied flow were then evaluated in relation to the theoretical framework, by presenting conceptual suggestions on how a RTLS could benefit the logistics management.
3.2 Case company

This thesis has been conducted in collaboration with Scania CV AB in Oskarshamn. Scania is a global market leading automotive manufacturer of trucks and buses. The company was founded in 1891 and has its headquarters in Södertälje, Sweden. Today, Scania is present in about 100 countries and has about 49,300 employees worldwide. Currently, Scania is in the middle of the greatest transition in the company’s history of transforming the company’s image and culture to become a new market leader of sustainable transports. (Scania AB, 2018)

Scania’s success can be traced back to its core values of Customer first, Respect for the individual, Elimination of waste, Determination, Team spirit and Integrity, which permeate the entire organization. These values have allowed Scania to create a culture of continuous development of its employees, products and organizations, and supported the company in having a proactive strategy of creating value for its customers. (Scania AB, 2018)

In Sweden, Scania has production sites in Luleå, Södertälje and Oskarshamn. The production plant in Oskarshamn was declared the world’s most modern cab manufacturing plant in 2017. In Scania Oskarshamn, 285 robots are synchronized to produce the cab body, before components are assembled at the lines. The produced cabs are then delivered to Södertälje (Sweden), Zwolle (Netherlands) or Angers (France) for final assembly, before delivery to the customer.
3.3 Research method

3.3.1 Case study

Due to the explorative nature of the study, a qualitative approach with a flexible research design was chosen. According to Jacobsen (2002) this allows for flexible adjustments of the research focus, design and execution dependent upon the discovery of new findings and is most suitable for situations wherein only limited knowledge of the studied phenomenon is available.

One of the most common research methods used within qualitative research is a case study, which also was selected for this thesis. This is based on the nature of the study, which implies that even though the two concepts of JIT and RTLS are recognized and researched, there still does not exist a satisfying number of practical frameworks that combine the academics common understanding of RTLS in relation to JIT. By combining the two concepts new theory is generated, based on their correlations and interconnections to achieve improved efficiency. This underlines the importance of selecting a research method that allows for an in-depth research study of the phenomena, as well as a method that allows for generating a theoretically based framework and testing it. Williamson (2002) explains that case studies are used for the description of phenomena’s and the development- and testing of theory. She continues to explain that case studies are especially appropriate when the researchers seek a deeper understanding of the context and when the field of interest is dynamic and has not yet matured. Based on this definition, case study was selected as the most appropriate method to use.

In order to fulfil the purpose of the thesis and answer the proposed research questions, the case study was designed to provide the study with empirical data from an operational level (the studied flow) as well as a managerial level of the logistics (general challenges of logistics management). Based on the selected method and the case study’s design, a broad amount of data from interviews, observations and internal documents was collected, which resulted in a triangulation of empirical data. The two dimensions of empirical areas where data was collected, also allowed for a triangulation when the framework was evaluated.

Furthermore, to create a visual overview of the studied flow, the process was illustrated by using the standardized visual tools and icons of a value stream map.

3.3.2 Deductive reasoning

Patel and Davidson (2011) define deductive and exploratory research as analysing and compiling two, or more, theoretical concepts to a conceptual framework, which is analysed and tested. They continue to outline that a key component of deductive research is using existing theories to understand and explain a studied phenomenon, or when existing theory is used to generate new hypothesis, which is then empirically tested.

This definition of deduction corresponds well with the nature of this study where two recognized and researched fields were combined to a framework, which then was tested on an operational- and managerial level. Hence, the nature of this study was deductive and explorative.
3.4 Data collection techniques

3.4.1 Literature search
To achieve a structured and systematic approach to the collection of theory and literature, the searches followed the six-step model presented by Patel and Davidson (2011). They explain that when literature is being collected, it is important to follow a systematic, methodical and critical approach. In this section, the six-step model by Patel and Davidson (2011) is presented.

**Six step model**
Patel and Davidsons (2011) present a general model for how to systematically collect relevant literature. They emphasize that a fundamental pillar when searching literature is to not consider it as a phase of the study, rather than to consistently search for information throughout the study.

Their model was used as a general cornerstone for all literature collected in this study.

1. Preparation
   The researcher takes a stand from the studies purpose and research questions and identifies the specific field of the study. It is important to reflect upon what is considered to be crucial aspects within the field, and how it can be delimited.

2. Conduct a desk work of the field and topic
   Literature reviews, handbooks and encyclopaedias are to be read, to gain a fundamental understanding of the field of interest.

3. Select relevant data bases
   Data bases that consist of relevant articles and information are identified. The researcher reflects upon what information can be collected from different sources.

4. Search for literature
   The researcher identifies search phrases and key words. It is important to consistently evaluate how the searches can be widened and narrowed.

5. Collect material
   The researcher continuously evaluates both how the search results correspond with the study’s purpose and the research questions, as well as analysing the authors of the published material and for whom it was produced.

6. Evaluate
   The researcher assesses whether enough literature has been collected, or if central aspects are still missing. It should also be considered if there has been any literature identified that can be removed from the study.

3.4.2 Interviews
According to Williamson (2002), interviews are usually conducted for collection of qualitative data, where the respondent’s opinions, knowledge or explanations regarding the phenomena is required. She outlines that an important aspect to consider when designing an interview is to what degree the interview should be structured. The structure
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of an interview refers to the amount of freedom given to the respondent to reflect and openly answer the questions. A highly structured interview is for example when all respondents are asked the same questions, in the same order and where response alternatives are provided. This is often sought out when a higher degree of generalizability is desired. It can be compared to conducting a questionnaire in person. Patel and Davidson (2011) also outline that it is important to consider the degree of standardization of the questions. Standardization refers to the degree of pre-prepared questions. A low degree of standardization means that a larger portion of the questions asked were developed during the interview. Hence, highly structured interviews are often conducted with a high degree of standardized questions.

For this thesis, interviews were conducted with two different purposes. Initially for exploratory purposes, to gain a broad and general understanding of the logistics management at Scania and to gather information of which internal material flow to study. Secondly, for explanatory purposes where individuals at the studied material flow were interviewed about their tasks and procedures.

**Exploratory interviews**

The exploratory interviews had a central role in order to first gain a broad and general understanding of Scania’s logistics management and processes related to their material flows, second to obtain an understanding of the local expertise and to identify a material flow that could be studied in the thesis.

For these interviews, seven employees with key knowledge and experience within Scania logistics were selected (see below). The interviews were conducted using a funnel technique, where the initial questions started broad and not specific. As the interview progressed, the questions got more directed and aimed at the objective of identifying a suitable flow to be studied. According to Patel and Davidson (2011), this is a common technique to create a safe environment where the respondent feels free to express themselves. The interviews were semi-structured, where prepared questions were used to guide the interview, rather than being strictly followed. The initially prepared questions for the exploratory interviews can be found in Appendix 1.

During the interviews, new questions were developed whenever further and deeper information was required. Follow-up questions was also used to clarify the respondent’s answers. The respondents’ received an invitation to the interview by email 25 working day in advance of the interviews. In the emails, both a presentation to the topic and the purpose of the thesis was provided. This allowed for a mental preparation before the interviews.

The interviews had a time limit of 60 min, and they were conducted in local meeting rooms at Scania.

The list below presents the positions of the interviewed respondents.

- Manager of logistics engineering, logistic centre
- Head of LEAN office
- Logistics coordinator, assembly workshop
- Project manager, logistics development
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- Manager of logistic development
- Group leader of logistics operations
- Manager of logistics, logistic centre

Explanatory interviews

Throughout the study, explanatory interviews were conducted to collect both quantitative and qualitative data from key individuals, related to or directly involved, in the studied flow. The main objective was to collect information about the current situation of the flow, as well as to identify deviations from the standard procedure. The characteristics of these interviews' varied dependent on the situation, context and what information was required. Hence, these interviews were semi-structured with both opened and closed questions. This allowed the respondents to both express themselves when needed, or for them to confirm observed data.

The list below presents the positions of the interviewed respondents:

- Project manager, logistics development
- Workshop technician, logistic centre
- Forklift driver, logistic centre
- Team leader, assembly line
- Truck driver, shuttle deliveries between logistic centre and assembly plant
- Team leader, logistic centre

3.4.3 Focus group

Duignan (2016) explains that focus groups are usually conducted for collection of qualitative data and when a group’s general and common opinion related to a topic is being researched. He continues to explain that focus groups are usually conducted with smaller numbers of participants, where the moderator’s mission is to guide and steer the progress to aim the discussion towards the topic of interest. According to Duignan (2016), the activity is often being recorded and data is being collected by documenting what is being observed. He also outlines that focus groups can be used in a post-result stage, where the findings of the study can be discussed, improved and challenged. Williamson (2002) provides a general framework, consisting of five stages, for setting up a focus group.

1. In the initial phases, the focus of the researchers is directed towards identifying wanted key characteristics of participants for the focus group. They should consider which function, departments or positions that needs to be represented?
2. The researchers use their networks and contacts to identify potential participants. They ask contacts to present individuals who they believe could be a suitable participant to the study.
3. This stage focuses on the location in which to conduct the activity. The researchers should select a safe and inspiring environment, preferably a location that is known to the participants and easy to access.
4. The researchers should estimate how much time is needed for the activity, this information should also be communicated to the participants together with the invitation.
5. In the last stage, the researchers prepare questions and gather the material they need. If several questions are to be asked, they decide on a time limit to each of the questions to ensure that the last questions do not get rushed through.
Williamson (2002) also highlights some pitfalls that researchers should be aware of and take into consideration when conducting a focus group:

- Some participants might be dominant and not leave enough space for others to contribute to the discussion with their opinion.
- Since the researchers lead the discussions, they have a great amount of influence over its direction. This might affect the results of the study, due to the researcher’s subjective opinion of events or scenarios.
- There are limitations to the possibilities of generalizing the results.
- Based on the open and creative nature of focus groups, the results are often challenging to interpret and summarize.

For this thesis, a focus group was created to discuss the study’s result and to elaborate on how the findings could be used for other internal material flows at Scania. Employees with key knowledge and experience within the field of logistics were invited to participate, please see the list of participants below:

- Manager of logistics development
- Project manager, logistics development
- Logistics coordinator, assembly workshop
- Logistic technician
- Project manager, logistics development

The invitation for the focus group was sent out 14 working days in advance, together with a general agenda and purpose. The scheduled time was 90 min. Seven people were invited, of which four accepted the invitation and participated in the activity. For the session, pre-prepared questions were developed and designed to be both broad and open, to allow the participants to freely respond and discuss the topics. One day before the focus group, a mail was sent to the participants where they were asked to reflect upon three main questions for the workshop (see Appendix 2). The mail allowed the participants to mentally prepare for the session, which added to the excitement of the activity and provided a possibility of having additional time to reflect over the questions before the activity.

The focus group session started with a 15 min presentation of the study’s aim and the purpose of the activity. This provided the participants with the necessary understanding of the RTLS concepts to constructively discuss the prepared questions. An overview of the design of the focus group can be found in Appendix 3.

During the session, the participants were asked to:

1. Identify the strengths and weaknesses at Scania in relation to logistics management and material flows. The strengths and weaknesses provided the foundation of the session, where the aim was to pinpoint the underlying causes of the often more visible symptoms in logistics. The first task was individual and lasted for 5 min. The answers were written down on Post-its.
2. Put the identified strengths and weaknesses on the white board, shortly present their answers and explain why they categorized their answers as strengths or weaknesses.
3. Discuss the identified strengths and weaknesses effects on the material flows at Scania. The purpose was to pinpoint examples of how Scania’s weaknesses and strengths affect the design and operation in logistic material flows. During this task, the participants were free to discuss and provide examples. The moderators
wrote down what was being discussed and noted the examples on new Post-its, which were also put on the whiteboard.

4. Analyse what type of information is required for each of the identified examples to enable Scania to work towards counteracting its weaknesses and enhancing its strengths.

3.4.4 Observations

Duignan (2016) describes an observation in academic research as the researchers systematically studying and documenting behaviours, without influencing what is being studied. Patel and Davidson (2011) also emphasise that observations must be conducted systematically, both the planning before the observation and how the observed information is to be documented. They furthermore explain that observations are a suitable technique to use when a phenomenon is required to be studied in its context and natural environment. Williamson (2002) outlines that there are four different types of observations and underlines that observations do not necessarily have to be systematic to be classified as an observation;

- **Ad libitum**: This technique of observation is most common in situations where the researchers have limited knowledge regarding the phenomena. The ad libitum approach is easy to recognize due to its characteristics of being a non-systematic technique.

- **Focal**: Is recognized for the active choice of the researchers to select a specific individual, group or event to be studied over a period of time. All events, related to the studied phenomena, is recoded and analysed.

- **Scan**: This approach aims at providing the researchers with a quick scanning, or a snapshot, of the studied phenomena at frequent intervals.

- **Behaviour**: This technique focuses on selecting a specific event or behaviour of interest. Then, instead of documenting everything related to a phenomenon, the study focuses on documenting who did what, when the selected behaviour occurred.

Williamson (2002) also explains that different techniques for recording and documenting can be applied to the different observation styles above, for example to continuously document the observed phenomena, or focusing only on documenting what is considered valuable.

Observations can be conducted for different purposes such as for exploratory purposes, in the initial phases of a study. In that case, information collected from the observations can make out the foundation for the progress of the study by allowing other data collection techniques to be used to complement the initial observations (Patel & Davidson, 2011).

For this study, observations have been used for different purposes, (1) initially to gain an overall understanding of how the material moves from the start of the flow, to the consumption point at line, (2) to define the processes in the flow of storages, buffers, transports and sequencing, (3) to map how information is distributed and identify how a need of material is triggered, (4) to collect data of cycle times, withdrawal frequency’s, transportation times and frequency’s, buffer capacity and occupancy, number of operators/fork lift drivers. Hence, the researchers used all the above mentioned observation
techniques where *Ad libitum* and *Scan* were used initially to gain an overall understanding of the flow and to gain the necessary knowledge to know which type of information was needed to be collected. *Focal* and *Behaviour* was later used to collect data and to identify which individual does what, when and why.

For the time studies (4) of the different stations within the flow, the researchers collected different amounts of data. This was due to the time constraints of the project and the fact that the availability to collect data at some of the stations was more restricted than on others. This led to that some of the average times, which are presented in chapter 4, are calculated based on fewer measurements, in comparison to others, but on average 7 measurements were taken. This in turn negatively effects the reliability of some of the data, which was counteracted by conducting supplementing interviews or retrieving data from the companies IT systems whenever possible.

### 3.4.5 Analyses of internal documents

Complementary information has been collected from Simas, Scania’s internal *Enterprise Resource Planning* (ERP) system. When a station triggers a need of material, the information is digitally transferred and registered in *Simas*. This created a valuable source of information for this study, since it allowed historical data to be considered. Specifically, reports of when material was requested within the flow were used for the study.

Scania Oskarshamn uses a digital list where deviations in material flows and supplies are being registered. In this list, information of quality defects, late deliveries from suppliers, wrong sequencing/picking/losses of material and assembly damages of parts/components are documented. Historical data from 21st of January to 8th of April related to the side panel flow was collected and analysed. The side panels accounted for a total of 264 reported incidents over this time period.
4 Findings and analysis

This chapter starts by presenting the findings from the interviews. These findings make out the identified general challenges within logistics management. The chapter then presents how the studied material flow was selected and what the findings from the flow were. The chapter ends with a summary and analysis of the studied material flow.

4.1 General challenges within the studied logistics management

Several general features of the Scania logistics and related problems were detected during the initial exploratory interviews and the concluding workshop, which are presented within the following subchapters.

4.1.1 High Complexity and space constraints

Since Scania offers their customers a high level of customization, especially when it comes to the features of the cabs, the internal logistics at Scania Oskarshamn have to manage more than 3000 different parts. Since the cabs are assembled on a conveyer belt with a rigorous cycle time and limited space in direct vicinity to the line, the logistics department at Scania Oskarshamn has to ensure the delivery of the right components at the right time. For this, the components are supplied to the line using different methods (e.g. delivery of sequenced and pre-kitted material), dependent upon the consumption frequency, the component size and the number of different variants for the specific component. This leads to a high complexity of the internal logistics management at Scania Oskarshamn. Furthermore, the internal logistics has to deal with transport capacity constraints on its transportation devices (trains, forklifts, trucks) and limited space availability for their supply paths, which can create bottlenecks and variances in transportation times in the supply to the line and make the transportation times of forklifts and trains unreliable.

4.1.2 Time constraints

There are several factors that influence the sequence in which cabs are to be assembled at the line, such as:

- The assembly of some cab variants require more time than others, which necessitates a levelling of the assembly of the different cab variants.
- The upstream painting process paints the cabs in batches, to minimize setup times. This has a direct effect upon which cabs are released to the line.
- Shortages of material from suppliers can result in that affected cabs are not allowed to enter the production line, before material has been received.
- Quality defects of material from suppliers might affect which cabs are allowed to enter the line.
- The assembly of some cabs require consumption of low frequency components, which affects the deliverability of logistic supplies to the line. Cabs requiring low frequency components must therefore be mixed with high frequency components, to balance the need of materials at line.
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This leads to that the cab sequence is not being finalized earlier than 70 min before the start of the assembly. For the internal logistics, this creates a narrow window of time to supply the lines with the right material at the right time.

4.1.3 Lack of transparency

The internal logistics management at Scania Oskarshamn also has to deal with the issues of having only limited transparency within their material flows. In relation to this, some “black holes” were highlighted several times:

1) The incoming goods area (until material is being put into storage)
   The material that arrives for the assembly of the cabs is unloaded at a canopy outside the assembly hall. Because a lot of different material arrives there and it is not being registered before it is put into the automated high-bay storage inside, a lot of unknown material is being stored intermediately at the canopy. Because, the material is only identifiable by a printed flag with a barcode on the pallets, and sometimes there’s even different materials on one pallet, it can create problems in quickly finding the right material there, if a shortage occurs inside. Furthermore, because there is no information on whether the material from the suppliers or even the Scania Logistic Centre, will be arriving on time, high safety buffers are kept. If a shipment arrives late, this can also lead to bottlenecks in unloading the incoming goods from the trucks.

2) The material flow from the retrieval of the storage to the consumption at the line
   The retrieval of material from the automated high bay storage is triggered by a manual scan from logistic operators, either directly at the line, or at the platforms where the material that is delivered by trains is prepared. A common problem there is that, because the operators do not get a confirmation or status report (e.g. material is on its way) of their order, they sometimes end up ordering the material again, which can lead to large “artificial” backlogs at the automated high bay storage and unnecessary transports. Furthermore, some of the respondents pointed out that Scania knows what is supposed to happen to the material after it is retrieved from the automated high bay storage, but this does not necessarily reflect the actual material flow, leading to uncertainties and risks, when changes are made to the logistics management.

3) The actual consumption and related stock of goods at the line
   A lack of data regarding the stock of goods at the line has been highlighted. Because the consumption frequency of a lot of components is either unknown or not made available to the people planning the resupply of the material, workarounds like increasing the safety buffers at the line, are being used.

To deal with these “black holes”, Scania is currently working with logistic platforms, which represent an extra safety buffer that allows for more flexibility and provide a room for covering errors. Problems within the internal material flows are therefore harder to detect and the material is handled more than necessary. Because of this increased material handling at various stations, it has also been pointed out, that it has become difficult to balance the workload at the different stations, which leads to a higher number of operators being required, than there would been needed. The management of uncertainty, by increasing the resources (like people and safety buffers) has also been mentioned in relation to forklifts, which in turn can be connected to the problem of space constraints in relation to supply paths (see subchapter 4.1.1).
4.1.4 Lack of Communication / Data Connections

As described within subchapter 4.1.3, a lot of the material has to be ordered or managed manually by the logistic operators. One reason for that is the lack of information sharing between different systems and departments, as can for instance be seen in the lack of information regarding the consumption or stock of material at the line. One interviewed respondent at Scania pointed out that it should be possible to retrieve that information from the ERP system, but it is currently not used for that purpose. This also has an effect on balancing the internal material transports, as another respondent indicated by calling attention to the possibility of levelling material retrieval from the automated high bay storage by resupplying low volume parts in times of low utilization. Another aspect that clearly shows the manual, rather than digital, management of the material flows, is that in some flows (as e.g. in the studied side panel flow”) the resupply of material to the line is controlled by using a limited amount of racks in the logistic loop. Representatives of the Logistic Centre have also pointed out that they are not aware of their status in relation to the consumption at the line. The lack of communication and data accessibility can be seen in the fact that there is no prioritization of material transports possible, when a bottleneck in transport capacity occurs. This has been pointed out, both in relation to the retrieval of goods from the automated high bay storage, as well as for the regular truck transports from the Logistic Centre.

4.1.5 JIT & Improvement Focus

The employees from Scania Oskarshamn describe their production and JIT logistics management as demand driven production, wherein most logistics employees put it in relation to the Just in Sequence of material. The Lean Manager of the plant does however admit, that JIT is not a focus point for the Lean initiatives at the plant. He furthermore pointed out, that historically their improvement activities have been focused upon decreasing the cycle time of the different stations on the line, to increase the output and better meet the high customer demand. Because of this and the limited space at the line, a lot of waste at the line has been removed, which has resulted in more material handling, buffers and additional handling within the supply flows. He furthermore called attention to that while waste reductions at the line could be measured in seconds, there are uncountable min of waste in the supply flows. The fact of having moved the waste from the line to the material flows has also been confirmed by the logistics manager, who pointed out that the platforms and trains are necessary in order to meet the low takt times at the line. Even though all departments and teams have their own Kaizen activities, it can be noticed that they are mostly focused on productivity, safety, quality or sustainability (like energy consumption reduction) instead of improving the overall efficiency. This is also reflected within the KPIs Scania is keeping. Overall, they are capturing the output and required rework of the assembled cabs at the line, while each department also follows up on individual KPIs like attendance rates or long-time sicknesses. The internal logistics department of the assembly area also keeps track of for
instance how many pallets are retrieved from the automated high bay storage in a limited time frame, showing once again that the focus is on productivity rather than efficiency.

4.1.6 Lack of reliable data
Another difficulty for improvement activities within the logistics at Scania is a lack of reliable data. A project leader, responsible for leading improvement projects, pointed out that the first part of improvement projects – the current state analysis – requires a lot of time and resources, because the data usually has to be captured manually. This also affects the ability to follow up on improvements, where Scania often thinks they have solved a problem, but they cannot be sure, because there is a lot of variation in the processes.

It has also been highlighted that the logistics managers are often not aware of where deviations from standard procedures occur, because deviations are only reported to the deviation list - Bristlistan - if the line has stopped or is at risk of being stopped. Deviations that do not affect the line, but do affect the efficiency of the supply flows, are therefore not captured. This supports the statement that Scania often knows that there might be problems within a flow, but they do not know where, since they can only see the effects on the line, rather than where in the material flow the issue has been caused. Currently, Scania is trying to detect the cause of the problems documented in the Bristlistan, by assigning a department as owner to all of the issues, that should follow up on the cause of the problem. It has however been pointed out that this often leads to problems being moved around from department to department, rather than them being addressed efficiently, because no one wants to take ownership of the issue.

The lack of reliable data has also been pointed out as a difficulty within the decision making at Scania, because it leads to situations where the subjective opinions of employees or managers are argued as facts, since facts are not available or easily accessed.

4.1.7 Employee Attitude
It has also been pointed out that the employees, working and actively contributing to the supply flows often lack an understanding of the overall internal supply chain. This can for instance be seen by workers at the logistic centre getting worried that they do not have “enough” empty racks, even though that would imply that there is more than enough material, waiting to be put into the cab at the assembly. Furthermore, it has been highlighted that the understanding of why pace and takt is important is lower within the logistic operators, as opposed to the operators at the line. The workers do however understand the importance of “keeping the line running”, which can lead to unreliable standards that are not necessarily being obeyed anymore, if there is a risk of stopping the line. This is also a reason for scepticism towards change within the workforce, because they are afraid of the change having consequences on their ability to deliver their products to the line in time.
4.2 Identification of the studied flow

Within Scania Oskarshamn there were several logistic flows that potentially could be suitable for this study. Hence, in the initial phase of the data collection, there was an evident need for defining what was to be considered a suitable flow. Based on the potential of RTLS and the concept of JIT, a suitable flow was defined to have the following characteristics:

- A vital flow where a late supply to the line could cause severe problems, e.g. production stops.
- Few components are transported together on one carrier.
- The ability to track and trace material is limited.
- Low degree of information transparency

During the exploratory interviews, one material flow was frequently discussed, this was the flow of side panels. The side panels can be either unpainted or painted. The unpainted side panels can be viewed as a standard part, due to that each individual side panel is not designated for one specific cab before the material is sequenced. The painted side panels on the other hand, are crucial components that are being ordered from suppliers in the same specific colour as the corresponding cab that is to be manufactured at Scania. This means that every painted side panel is designated for one specific cab, already from the point of order to the suppliers. The suppliers deliver the side panels to Scania Logistic Centre, which is at a different location, located about 2.5 km away from the production site. In the Logistic Centre, the side panels are sequenced before delivery to the Production Site. The side panels are assembled in pairs to every cab, on one of the production lines. The line has a fixed sequence of cabs, which means that the side panels must arrive in the same corresponding sequence as the cabs on the line to avoid a production stop.

Internally between the Logistic Centre and Production Site, the side panels are transported in specially designed racks that fit only a few parts. For this reason, these racks are considered as internal racks and they are continuously circuiting in a closed loop between the two sites.

The flow of side panels lacks information transparency, which is resulting in daily challenges related to knowing where material is, and when the next supply will arrive. As a result, wrong sequencing, picking and lost material of side panels’ account for 10.2% of the reported incidents related side panels in the deviation list, Bristlistan. The lack of information also results in that team leaders on the shop floor sometimes have to call connected processes in the flow, to stress material deliveries or to investigate where certain articles are located.

Based on these factors and the definition presented above of what aspects that make a suitable flow, the decision was made to select the flow of side panels for this study. This flow was also considered suitable due to that it is a closed loop of racks and that the Logistic Centre, could be viewed as a supplier to the production site, which added an additional dimensional to the flow. Because of that it allowed the study to investigate how the flow is managed between two sites as well.
4.3 Side panel flow

Within the flow, only the painted side panels are ordered from suppliers in the same colour as the corresponding cab that is being manufactured at the line. For this reason, the buffer of unpainted side panels at the sequencing station, Logistic Centre, was considered to be static and not investigated. This means that for this study, the operations before the sequencing operation only the painted side panels were investigated, and not the unpainted side panels.

The flow has been identified to start from the point in time when the forklift operator picks up new painted side panels at the incoming goods storage, until the material is consumed at the line.

An illustration of both the supply flow of material and the return flow of racks is presented in Appendix 4. To provide a holistic view of the entire flow, both the material supply from the external supplier and the incoming goods storage is presented, even though this is not considered to be part of the flow for this study.

The supply flow consists of the following steps:
- Seven buffers
- Six forklift operations
- One picking operation
- One sequencing operation
- One truck transport (between the sites)
- One train transport (internally at the production site)

And the return flow of the following steps:
- Six buffers
- Five forklift operations
- One truck transport (between the sites)
- One train transport (internally at the production site)

Within the flow, side panels are mostly pulled from upstream stations once a need is triggered downstream. However, the Logistic Centre receives two notification when material is needed at the lines, (1) the forklift operator who picks painted side panels and supplies the buffer at the sequencing station, receives a notification of which specific side panel to pick once the fixed sequence of the cabs on the line is final. This signal is sent 360 min before the material is needed at the line. (2) The sequencing operator receives a notification 93:48 min before the material should arrive to the line buffer.

The loop of internal racks is designed to stimulate a pull flow of the material by ensuring that the right rack is delivered in the right sequence to the line. The racks are flagged with a number of 1 to 12 at the sequencing station, Logistic Centre. The closed loop of internal racks consists of a total of 24 racks. In each rack, there is an average ratio between painted and unpainted side panels of 44.75% painted and 55.25% unpainted.

In the following subchapters each station of the side panel flow is described in detail.

4.3.1 Forklift 1– Logistic Centre

The Forklift 1 operator has the following responsibilities and should work according to the following standard:
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- Supply the Pallet Racking Storage with material, when two racks are empty. The two empty racks are considered a signal for the forklift operator to deliver the two empty racks back to the Incoming Goods Storage, and in the same operation pick up two full racks with painted side panels, which are to be supplied to the Pallet Racking Storage. Close to the sequencing station, the operator puts down the two racks, steps out of the forklift and goes to a computer to register which rack has been picked up and which specific painted side panels it contains. The operator then receives information from the system of where in the Pallet Racking Storage the two racks are to be stored.

- Supply the Buffer at the Sequencing Station with painted side panels. The forklift operator receives a signal 360 min before material is needed at the line, but not when the material should be supplied to the buffer at the sequencing station. Hence, the processes are reliant on the Forklift 1 operator to supply material at the same time, or faster, then the sequencing operator withdraws material from the buffer.

- Deliver sequenced material from the Sequencing Station to the Moving Floor. This transport is located internally at the Logistic Centre (see 4.3.5).

4.3.2 Pallet Racking Storage – Logistic Centre

The Pallet Racking Storage at the Logistic Centre is located next to the Sequencing Station. The storage has got a capacity of 348 painted side panels, and an average occupancy of 77%. In this area, Forklift 1 supplies and delivers material in and out of the storage. The forklift is installed with a computer and a screen that provide the operator with the information of which painted side panel to supply to the buffer at the sequencing station. Once the sequence on the line is fixed, a request is triggered for specific material. The operator brings down the rack from the storage, steps out of the forklift, manually withdraws the requested painted side panel pair from the rack, and supplies the buffer. The operator then writes down the number of the rack to which the material got supplied on a paper, which later is handed over to the sequencing operator.

To this storage, painted side panels are being supplied in pairs of 8, in the same operation.

4.3.3 Buffer at sequencing station – Logistic Centre

To avoid a shortage of painted side panels at the sequencing station, a buffer is used. It is being supplied by Forklift 1. This buffer has a capacity of 24 pairs of painted side panels and the average occupancy is 83%. The buffer is located next to the internal racks that the side panels are being sequenced to.

4.3.4 Sequencing operation – Logistic Centre

At the sequencing station, painted and unpainted side panels are picked and sequenced, according to the fixed sequence of cabs on the production line. In this station, the operator is responsible for (1) sequencing the side panels to the correct rack, (2) check the material for quality deviations, (3) request new unpainted side panels when the buffer minimum has been reached and (4) request pickup of the sequenced material.

This station has three designated spots for internal racks, to which painted and unpainted side panels are being sequenced, according to the cab sequence. The operator receives the sequencing order through a printer that prints out individual labels for all
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the side panels. The printing of these tickets is triggered 93:48 min before the material is needed at the line. Before the operator starts to pick the right parts for the sequence, he/she waits for all the tickets for one rack to arrive, in order to keep the supply to the line steady and to avoid pushing material. Once all the tickets for one rack have arrived, the operator compares the requested painted side panel with the hand written paper that Forklift 1 provided, this is to identify where in the buffer the painted side panels are placed. The operator then carries the tickets while he/she starts to pick the unpainted and painted side panels, as well as some small items that are assembled together with the side panels at the line. During every pick of side panels, the operator conducts a visual control to ensure that the tickets requested article number corresponds with article number on the painted side panel. After all the side panels for one rack have been collected, the operator puts a label with the rack number (from 1 to 12) on it and scans a bar code, which informs the Forklift 1, that this rack is now ready for pick-up. The pick-up of the racks, however, is organized in pairs, which means that Forklift 1 waits for the scan of two filled racks, before the racks are picked up and delivered to the line. Since there are three designated spots for the internal rack, the operator of the picking station can start on the third rack while the first two are delivered to the moving floor and two new empty racks are brought to the picking station (see 4.3.5). As previously mentioned, each rack is flagged with a number from 1 to 12. When Forklift 1 delivers two empty internal racks, the operator therefore has to manually collect the flags on the racks, before he starts to pick the material for these racks. The measured times related to the sequencing station can be found in Table 1.

**Table 1 - Measured Times, Sequencing Station**

<table>
<thead>
<tr>
<th>(H:MM:SS)</th>
<th>Sample#</th>
<th>Average</th>
<th>St. Deviation</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Picking and sequencing Time</td>
<td>6</td>
<td>0:07:47</td>
<td>00:01:06</td>
<td>0:06:25</td>
<td>0:09:30</td>
</tr>
<tr>
<td>(2) Waiting Time of one filled rack until transport</td>
<td>6</td>
<td>0:07:16</td>
<td>00:04:58</td>
<td>0:02:30</td>
<td>0:12:35</td>
</tr>
</tbody>
</table>

4.3.5 Pickup of sequenced side panels – Logistic Centre

Forklift 1 is responsible for the picking up and the transport of the sequenced side panels from the Sequencing Station to the Moving Floor. Forklift 1 should always deliver two racks with sequenced side panels at the same time, to optimize efficiency. The operator receives a notification, sent from the sequencing operator, when one sequenced rack of side panels is ready for pick up. This means that the Forklift 1 operator must wait until a second rack is ready, before being allowed to pick up the racks and transporting them to the Moving Floor. In the same operation, when Forklift 1 delivers material to the moving floor, the operator also picks up two empty internal racks from the Empty rack buffer and resupplies them to the Sequencing station.

Even though the Forklift 1 operator should only perform this transport when two racks have been sequenced and ready, it was observed that the operator sometimes initiates the procedure with only one rack. The operator explained that sometimes when he/she
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has got some time over and wants to work ahead, one rack with material might be del-
ivered and one empty rack resupplied to the Sequencing station. The measured times
related to the transports between the sequencing station and the moving floor can be
found in Table 2.

Table 2 - Measured Times between Moving Floor and Sequencing Station

<table>
<thead>
<tr>
<th>(H:MM:SS)</th>
<th>Sample#</th>
<th>Average</th>
<th>St. Deviation</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Transport of filled rack to the moving floor</td>
<td>5</td>
<td>0:02:20</td>
<td>0:00:07</td>
<td>0:02:11</td>
<td>0:02:28</td>
</tr>
<tr>
<td>(2) Transport of empty rack to the sequencing station</td>
<td>4</td>
<td>0:02:19</td>
<td>0:00:53</td>
<td>0:01:49</td>
<td>0:03:38</td>
</tr>
</tbody>
</table>

4.3.6 Outbound buffer (moving floor) – Logistic Centre
This is a temporary buffer which usually contains of two racks with sequenced side
panels. It is located on top of a moving floor, which works as a conveyor that automatically loads the trailers of the shuttle trucks that transport material between the Logistic Centre and the Production Site. The truck drivers should activate the loading procedure 3 min before departure, to allow the longest possible window of loading. In Table 3, the average waiting time that two racks with sequenced side panels wait on the moving floor, which also includes the transport time onto the truck, is presented as well as the actual time it takes for the material to be moved onto the truck.

Table 3 - Measured Times, Moving Floor

<table>
<thead>
<tr>
<th>(H:MM:SS)</th>
<th>Sample#</th>
<th>Average</th>
<th>St. Deviation</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Waiting time on moving floor</td>
<td>6</td>
<td>0:12:08</td>
<td>00:08:18</td>
<td>0:04:32</td>
<td>0:26:27</td>
</tr>
<tr>
<td>(2) Conveyor unloading/loading of truck</td>
<td>4</td>
<td>0:03:00</td>
<td>00:00:10</td>
<td>0:02:53</td>
<td>0:03:15</td>
</tr>
</tbody>
</table>

4.3.7 Empty rack buffer – Logistic Centre
The empty rack buffer is located next the outbound buffer. In this buffer, racks that have returned to the Logistic Centre from the Production Site are stored, before being reintroduced to the internal flow-loop again. This buffer contains a constant number of 4 racks, and if a return delivery of racks just arrived, there will be 6 racks for a shorter period of time.

4.3.8 Transport between Logistic Centre and Production site
The shuttle transports between the Logistic Centre and the Production Site is operated by three trucks. The route is outsourced to a subcontractor, and the drivers follow a fixed driving schedule which outlines when arrival and departure from both locations should be. According to the schedule, a new supply of material is planned to arrive the Production Site in average every 18:13 min. Every delivery between the Logistic Centre and Production Site, should contain two racks in each direction. Presented in Table 4
Findings and analysis

are the times that the truck driver has for the three activities of driving, unloading and loading, according to the fixed schedule.

*Table 4 - Calculated Times from planned schedule of transports*

<table>
<thead>
<tr>
<th>(H:MM:SS)</th>
<th>Sample#</th>
<th>Average</th>
<th>St. Deviation</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Driving time between the sites</td>
<td>18</td>
<td>0:08:09</td>
<td>0:00:46</td>
<td>0:08:00</td>
<td>0:12:00</td>
</tr>
<tr>
<td>(2) Unloading and loading at the Logistic Centre</td>
<td>18</td>
<td>0:17:46</td>
<td>0:01:35</td>
<td>0:15:00</td>
<td>0:26:00</td>
</tr>
<tr>
<td>(3) Unloading and loading at the Production Site</td>
<td>18</td>
<td>0:17:25</td>
<td>0:01:51</td>
<td>0:15:00</td>
<td>0:27:00</td>
</tr>
</tbody>
</table>

However, it was observed that the truck drivers do not always follow the fixed schedule. The drivers explained that this is because of that the schedule sometimes clashes with their planned breaks. The consequence of that the schedule is not followed is that trucks might be queuing to load/unload and that the two sites cannot be certain of when the next arrival will be. In Table 5, the times observed for the same activities as in Table 4 is presented, as well as how frequent the deliveries of new supply to the Production Site is.

*Table 5 - Measured Times of transports, Logistic Centre and the Production Site*

<table>
<thead>
<tr>
<th>(H:MM:SS)</th>
<th>Sample#</th>
<th>Average</th>
<th>St. Deviation</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Driving time between the sites</td>
<td>7</td>
<td>0:07:23</td>
<td>0:04:44</td>
<td>0:03:00</td>
<td>0:18:00</td>
</tr>
<tr>
<td>(2) From arrival to departure at the Logistic Centre</td>
<td>5</td>
<td>0:23:24</td>
<td>0:08:32</td>
<td>0:11:00</td>
<td>0:34:00</td>
</tr>
<tr>
<td>(3) From arrival to departure at the Production Site</td>
<td>8</td>
<td>0:12:37</td>
<td>0:02:00</td>
<td>0:10:00</td>
<td>0:17:00</td>
</tr>
<tr>
<td>(4) Frequency of truck arriving at Production Site</td>
<td>8</td>
<td>0:23:17</td>
<td>0:14:44</td>
<td>0:10:00</td>
<td>0:52:00</td>
</tr>
</tbody>
</table>

4.3.9 Forklift 2 – Production site

Forklift 2 operates at the goods arrival area in the Production Site. Forklift 2 is responsible for unloading material off the trucks that are arriving from the Logistic Centre and reload them with return racks and empty pallets before departure. There is no specific order in which the Forklift 2 operator unload the trucks, hence, the operator is free to unload the truck in the best way that they find suitable. When unloading the trucks, the Forklift 2 operator directly transports and places the side panels in the Inbound buffer (Canopy). Since the process of unloading and loading the truck is interconnected and not clearly separated, the total time of the process is presented in Table 6.

*Table 6 - Measured Times, Arrival area at Production Site*

<table>
<thead>
<tr>
<th>(H:MM:SS)</th>
<th>Sample#</th>
<th>Average</th>
<th>St. Deviation</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Unloading and loading the trucks</td>
<td>8</td>
<td>0:12:37</td>
<td>0:02:00</td>
<td>0:10:00</td>
<td>0:17:00</td>
</tr>
</tbody>
</table>
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4.3.10 Inbound buffer (Canopy) – Production site
The inbound buffer is located in the same location as the goods arrival area, at the Production site. The buffer is not a formal buffer, it is rather a temporary storage outside of the standard process. As a result, there is no capacity, nor average occupancy for the Inbound buffer. However, the buffer has an average of 3 racks, and the min/max amount of racks observed was 1 to 6 racks.

4.3.11 Forklift 3 – Production site
The supply of a rack to the IT Torget is triggered by the return flow of an empty rack through the train that connects the line and the platforms (see 4.3.15). On its way back to the platform, the train makes a re-supply stop, during which the train operator scans the label of the empty rack, which results in a signal at Forklift 3 to deliver the rack, that is carrying the label six numbers higher than the scanned label. The response time (from scan to delivery at the IT Torget) for this, as well as the actual transport time are presented in Table 7. Here it can be observed that the response time is rather volatile, compared to the actual transport time. This is largely caused by the circumstance that the Forklift 3 is also responsible for the delivery of other items from the Canopy to the IT Torget or other destinations.

Table 7 - Measured Transport Times, Forklift 3

<table>
<thead>
<tr>
<th>(H:MM:SS)</th>
<th>Sample#</th>
<th>Average</th>
<th>St. Deviation</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Response Time (from Scan to Delivery)</td>
<td>9</td>
<td>0:04:42</td>
<td>0:02:16</td>
<td>0:02:03</td>
<td>0:06:58</td>
</tr>
<tr>
<td>(2) Transport Time from Inbound buffer (Canopy) to IT Torget</td>
<td>7</td>
<td>0:01:08</td>
<td>00:00:14</td>
<td>0:00:50</td>
<td>0:01:30</td>
</tr>
</tbody>
</table>

4.3.12 Temporary buffer (IT Torget) – Production site
The “IT Torget” is an additional buffer before the delivery to the platforms, that has the purpose of a “hand-off” between the forklift operating under the canopy (Forklift 3) and the forklift delivering the goods to the platforms (Forklift 4), which is only operating inside. It has therefore the purpose of decreasing transport complexity for the individual forklift operator and enabling a team division between the platform supply - and the canopy management.

The IT Torget has a designated area for the incoming material and the outgoing empty racks. The waiting time after a side panel rack has been delivered to the incoming material area of the IT Torget by Forklift 3 is presented in Table 8. It has on occasion been observed that at times there are two Side Panel racks on the incoming material area of the IT Torget simultaneously, even though this is not supposed to happen if the process is following the standard.

In the return flow of the side panel racks, the waiting time of the empty rack at the outgoing area of the IT Torget has been observed to be shorter than the time the racks spent at the incoming material area as can also be seen in Table 8.

Table 8 - Measured Times, IT Torget
Findings and analysis

<table>
<thead>
<tr>
<th>(H:MM:SS)</th>
<th>Sample#</th>
<th>Average</th>
<th>St. Deviation</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Waiting Time at IT Torget (filled rack)</td>
<td>9</td>
<td>0:04:27</td>
<td>0:01:57</td>
<td>0:02:21</td>
<td>0:07:52</td>
</tr>
<tr>
<td>(2) Waiting Time at IT Torget (empty rack)</td>
<td>9</td>
<td>0:02:19</td>
<td>0:02:15</td>
<td>0:00:01</td>
<td>0:06:15</td>
</tr>
</tbody>
</table>

4.3.13 Forklift 4 – Production site

While Forklift 3 is equipped with a screen, that shows the operator which racks to bring inside, Forklift 4 is not specifically informed of which material to deliver. Instead, it follows a specific pattern of delivering different materials from the IT Torget and the adjacent seat buffer to their designated destinations. In relation to this it has been observed that frequently a team leader with an extra forklift must support the Forklift 4 operator in delivering the items from the IT Torget, in order to prevent a material shortage at the platform or the line. This does however not affect the transport time from the IT Torget to the Platform, but it can be noticed more within the variation of the waiting time at the IT Torget or at the Platform.

The actual transport process for Forklift 4 in relation to the side panel flow is to pick up the full rack from the IT Torget, deliver it to the platform, replace the empty rack there with the full rack and deliver the empty rack back to the IT Torget. Since the platform has two designated spots for the side-panel racks (see 4.3.14) the forklift operator has to do a visual control to ensure the right designated spot is replenished. The measured time for this process can be found in Table 9.

Table 9 - Measured Transport Times, Forklift 4

<table>
<thead>
<tr>
<th>(H:MM:SS)</th>
<th>Sample#</th>
<th>Average</th>
<th>St. Deviation</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Transport to Platform</td>
<td>9</td>
<td>0:01:45</td>
<td>00:00:26</td>
<td>0:01:03</td>
<td>0:02:13</td>
</tr>
<tr>
<td>(2) Delivery to IT Torget</td>
<td>9</td>
<td>0:00:52</td>
<td>00:00:13</td>
<td>0:00:30</td>
<td>0:01:20</td>
</tr>
</tbody>
</table>

4.3.14 Platforms – Production site

The assembly of the cabs in Oskarshamn is organized into several assembly lines. For each of these assembly lines a separate platform is responsible for pre-picking and loading the parts that need to be delivered to the line on a train that is designated to that line. The amount of material, that is required for the assembly line, where the side panels are installed in the cabs, is very high, which is why for this line the material is delivered on two trains. Usually the trains are aligned to the cycle time of the assembly line, by delivering new material every eights takt. Since, for this line, two trains are delivering material, a new train arrives every fourth takt. But while some material is re-supplied every time (every fourth takt), other material is only re-supplied with one of the two trains (every eights takt). This also has an effect on the set-up of the platform, because it needs to reflect the different set-ups of the trains.
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The side panels are one of the materials that are delivered to the line every fourth takt. Therefore, the platform has two different designated spots for the side panel racks, of which one is usually filled with material and waiting to be delivered to the line, while the other one has just been loaded of a train, and waiting to be switched out with a new filled rack from the IT Torget. Looking at the measured times related to this (see Table 10), it can be observed that the waiting time of the filled racks at the platform (1) is higher than the waiting time of the empty racks (3), especially if it is taken into consideration that the train is not leaving the platform right after the filled side panel rack has been loaded onto the train (2).

Table 10 - Measured Times, Platform

<table>
<thead>
<tr>
<th>(H:MM:SS)</th>
<th>Sample#</th>
<th>Average</th>
<th>St. Deviation</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Waiting time at the Platform (filled rack)</td>
<td>8</td>
<td>0:12:42</td>
<td>0:04:38</td>
<td>0:08:17</td>
<td>0:21:10</td>
</tr>
<tr>
<td>(2) Waiting time at the Platform (filled rack) incl. time on train</td>
<td>5</td>
<td>0:15:18</td>
<td>0:02:00</td>
<td>0:13:41</td>
<td>0:18:33</td>
</tr>
<tr>
<td>(3) Waiting time at the Platform (empty rack)</td>
<td>7</td>
<td>0:08:24</td>
<td>0:02:43</td>
<td>0:04:20</td>
<td>0:11:09</td>
</tr>
</tbody>
</table>

4.3.15 Trains – Production site

As described in subchapter 4.3.14, the side panels at the focal assembly line is replenished through two trains that leave the platform every fourth takt. In Table 11, the measured transport times for the side panels of the trains are presented. Both trains supply material to both sides of the line, and the side panels are delivered to one of the last stations on the route.

Once the material has been supplied at the line and the trains starts to drive back to the platform, the trains make an additional stop to drop off empty boxes and pallets. At this stop, the train operator leaves the train and manually scans the empty side panel rack, in order to trigger a request for the next rack in the sequence. This signal is directly transmitted to the operator in Forklift 3, who is responsible for supplying the next rack with sequenced side panels.

Table 11 - Measured Times, Trains

<table>
<thead>
<tr>
<th>(H:MM:SS)</th>
<th>Sample#</th>
<th>Average</th>
<th>St. Deviation</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Time to line</td>
<td>8</td>
<td>0:09:14</td>
<td>0:01:46</td>
<td>0:07:18</td>
<td>0:12:10</td>
</tr>
<tr>
<td>(2) Time back to Platform</td>
<td>9</td>
<td>0:02:22</td>
<td>0:00:16</td>
<td>0:02:04</td>
<td>0:02:45</td>
</tr>
</tbody>
</table>

4.3.16 Production line buffer – Production site

At the assembly line, which represents the consumption point for the side panel flow, there are two designated spots for the side panel racks. This is according to the “two bins” replenishment rule that is used for most materials throughout Scania Oskarshamn’s assembly. This rule dictates that once a bin, or in this case a rack, is empty,
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the operator moves on to using the material from the second bin/rack, while the first bin/rack is being replenished. In regards to the specific side panel flow it could be observed that the exchange of the empty rack for a new rack is very timely after the rack has been emptied, which shows that the transport of the new rack by the train, is rather well aligned with the cycle time of the assembly line.

4.4 Summary and analysis of the side panel flow

4.4.1 Summary of the flow data

In order to create a visual overview of the captured data from the side panel flow described in subchapter 4.3, a chart for both the supply flow of the side panels to the line (see Figure 8) as well as the return flow of the empty racks (see Figure 9) was created. The charts are inspired by the style of a boxplot diagram, with the blue data points representing the measured minimum and the purple points representing the measured maximum for each station. The middle line of the boxes shows the calculated average, while the upper and lower limits of the boxes illustrate the calculated standard deviation of the data collected for each station. Because the throughput time of the Pallet Racking Storage (with a capacity of 348 painted side panels) and the buffer at the sequencing station (with a capacity 24 painted side panels) would have been notably higher than the time of the rest of the processes, which would have lowered the quality of visual illustration they have been excluded from these charts.

![Figure 8 - Chart of Side Panel Flow Times](image-url)

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4.4.2 Analysis of the flow

On a general level, one of the main findings is that the farther away from the production line the studied process is, the more the process relies on individual judgement of when to conduct certain tasks. This creates an unbalance in the flow, and it might provide an explanation for why these processes have larger standard deviations. From the Inbound buffer (Canopy), all material is pulled from the downstream processes (starting from the standardized replenishment of material at the line by every train-loop), resulting in rather balanced and controlled flows. However, when studying the upstream processes before this buffer, most material is continuously being pushed. This has a negative effect on the flow as a whole, where interconnected processes might be hindered to perform their tasks and where unplanned buffers and temporary storage areas are created. It also creates higher uncertainties related to knowing when material will arrive, or when the next replenishment will be. This uncertainty might lead to that team leaders on the shop floor start to support a process, even though it might not be necessary or that employees start to feel stressed because they are uncertain of whether they will be able to conduct their work in time or not.

Another observation that becomes obvious by looking at the charts, is that the transport times in general have a much lower variance than the waiting times at the different buffers. This provides an insight into the reliability of the transport frequency, since the material waits for an uncertain amount of time. High waiting times can also be an indicator that the arrival and pick up transport are not well aligned. An exception for the
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low variance within the transport times are the driving times of the trucks between the two different sites.

A further general observation regarding the flow is that it consists of a lot of in-between buffers and requires a lot of manual handling. Looking at the overall process, its purpose is to:

1. receive the side-panels from the supplier,
2. order them in the right sequence to the production line and
3. deliver them in the right time, to the right place and in the right quality.

To achieve this, the process is currently set up with 9 stations that require a manual handling of the parts, or the rack that holds the parts. Apart from this leading to a relatively long overall lead time for a comparatively simple task, the high variabilities of the individual process steps affect the variability in upstream steps, and therefore also the overall uncertainty within the process. This leads to the need of safety stock being kept throughout the process, which in turn affects the lead time.

Another reason for why Scania keep safety buffers in this material flow, is that often the transporting resources (e.g. forklifts or trucks) are also part of other material flows to the line, and there is no information made available to e.g. the forklift drivers of which transport should be prioritized, when there is a bottleneck in the transportation.

Apart from these general aspects regarding the studied flow, some areas especially stood out when the data was analysed, because of the effects these operations have on other processes within the flow:

**Forklift 1:**

The manual handling and individual judgement that is required by the operator of Forklift 1 has been identified as a notable aspect, when analysing the side panel flow.

Forklift 1 is fully dedicated to the side panel flow, by either delivering side panels to the Pallet Racking Storage, replenishing the buffer at the Sequencing Station or delivering sequenced racks to the moving floor. It was observed that this allows for individual judgement and prioritization of some tasks over others. This was evident when e.g. Forklift 1 was late with a delivery to the moving floor, due to a replenish of material to the Pallet Racking Storage of only one rack. This in turn had the consequence of a truck leaving the Logistic Centre without the required two side panel racks. This could provide an explanation for the safety buffer of racks at the Inbound buffer (Canopy) at the production site. Deviations like this can also be explained by a lack of enforced standards for the task of operating Forklift 1. Since the operator is not given specific information of when to perform a specific task, it is up to the individual to decide if they for instance want to deliver only one rack, instead of the two, which is in violation of the defined standard. This underlines an important finding, that there is a lack of information provided to the Forklift 1 operator. Furthermore, there is no back loop to the Forklift 1 operator about stoppages at the line, meaning that this station continuous to push material, even though there is no longer a pull from the production site.
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The last aspect that needs to be pointed out in relation to the Forklift 1 driver is that this station pre-picks parts, that later are picked again at the following station, which highlights the over processing of the material in this flow. The information of where the parts have been pre-picked to, is then also handed to the Sequencing operator without a digital trail, but through a piece of paper that is filled out by hand.

**Sequencing station:**

Regarding the sequencing station, some interesting findings was identified. As mentioned in chapter 4.3, there are a total of 24 internal racks but only 12 rack-flags. This is to ensure that no more than 12 racks are circuiting internally in the flow and that material is not being pushed from the Logistic Centre to the Production Site. However, at the Sequencing station, the operator has several flags for each number. So, when the operator collects the rack-flags of the empty internal racks, and reflags them before a pickup is requested, more racks (and thus also more material) are introduced to the loop than what the flow was designed for. This could result in that e.g. while rack 1 is at the line, a new rack with the same flag number could be on the Moving floor at the Logistic Centre. This means that even though the 12-rack system is designed to limit the ability to push material, the reflagging of racks enables just that. Another interesting aspect related to this was that employees at the Production Site was not aware of that more racks and material was in the loop, which sometimes added to the confusion to why and how so many racks could be at the Production Site at the same time. The fact that more racks are being used to the loop also got evident when one of the employees at the Logistic Centre stated that they sometimes do not have any empty racks, they then have to call the Production Site to ask what is going on. This underlines that there is a strong uncertainty related to where the racks are and also a lack of knowing when the material is needed and when it should be delivered. The uncertainty aspect can also be found at this station, where the only signal the operator receives is the corresponding number of tickets that one rack carries. Once this signal is received, the operator does not know when the two sequenced racks should be finished and ready for pick up. The sequencing procedure described in chapter 4.3.4 illustrates that the picking and sequencing of side panels are rather manual and reliant on that no mistakes are done by the individual. The printed tickets can be dropped or mixed up when the operator is picking and sequencing, or the handwritten paper, that contains information of where each painted side panel is located in the buffer, might get lost or the hand writing on the paper might be hard to read. These aspects add to the assumption that even though the sequencing process is steady with a low standard deviation, the process is limited due to the manual searching and controlling required.

**Truck transport between the sites:**

One of the most interesting processes to analyse is the times of how the material is being delivered between the Logistic Centre and the Production Site. According to the driving schedule there should be a new delivery of material arriving at the Production Site every 18:13 min, however, the frequency of trucks arriving was 23:17 min with a standard deviation of 14:44. This shows that there is a large uncertainty in the process of when material arrives at the Production Site, and it might be an explanation to why side panels
are being temporarily stored in the Inbound buffer (Canopy), to ensure that a material shortage does not occur.

Out of the three activities (driving, arrival and departure at the two sites) it is also interesting that the average times are lower than the planned schedule, except for the arrival and departure at the Logistic Centre. From what was observed, it seemed like the truck drivers managed to finish the driving and unloading at the Production Site faster than planned, resulting in that additional time could be spent at the Logistic Centre. This could provide an explanation to why the stop at the Logistic Centre takes much longer, in comparison to the stop at the Production Site, especially considering that the trucks are unloaded and loaded by a conveyer system in 3:00 min / unloading/loading, and that material can be placed on the moving floor before the truck is on site. Taken this in to consideration, the stop at the Logistic Centre should in fact be faster than the stop at the Inbound buffer (Canopy).

When analysing the data for the truck’s activities and what was observed during the study, it seems like the planned schedule does not reflect the actual times that all the operations in a transportation loop between Logistic Centre and Production Site takes. This creates an uneven balance were the truck drivers feel either relaxed because they feel that they can drive in time losses or feel stressed because of a deviation occurred on the route before and the Production Site is now wondering why the material is late. As a result of this process being unbalanced and rather unreliable, the whole side panel flow is affected. Material is being pushed to the trucks to not miss a delivery to the Production Site, and an unnecessary large buffer is created at the Inbound buffer (Canopy), where up to 6 racks with sequenced material sometimes was observed.

**Trains:**

During the study, traffic jams occasionally occurred between the trains that supply the side panels, and an additional train that supplies material to another line. This resulted in a stressful situation where team leaders on the shop floor decided to step in and support the train operator to replenish the buffers at the line. The traffic jams also had an effect on the window of time that the train operator later hade to resupply the train with material for the next departure.

**4.4.3 Categorization of identified challenges**

To create a clear structure, the identified challenges within the flow are categorised below. By conducting a categorizing, a more transparent image of the overall challenges can be achieved, where finding a solution to one category could potentially solve several identified challenges within the flow.

Presented below is a categorization of the main challenges from the flow of side panel flow.

**Complex logistic structure**

- The data shows that even though the logistic transports of the side panels in general are rather steady processes, the waiting times until pickup varies. This supports the assumption that forklift operators are conducting several logistic transports of other material, in addition to side panels. This creates an additional
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challenge, where external factors have a direct impact on the flow and its capabilities.

Pull strategy with partial push material flow
- At the Production Site, the flow is designed to pull material from upstream processes once material is needed. This is done by either having the standardized replenishment cycle of material at the lines every train loop, or by operators sending a signal to an upstream process that new material is needed. However, Forklift 1 and the Sequencing operator at the Logistic Centre receives two CONWIP signals, in two different points in time. Even though the CONWIP signal is designed to limit the amount of WIP, the signal does not contain information of when a task should be performed nor when it should be delivered to the next process. This results in that material is pushed from the Logistic Centre, which results in that material is being stored at the inbound area, which in turn creates the Inbound buffer (Canopy).
- In the loop, the number of racks has been limited to 12, to create a standard that limits the possibilities to work ahead and push material in the flow. However, the reflagging of racks at the Sequencing station allows for more racks, and ultimately more material, being introduced to the loop. This enables the Logistic Centre to continue to sequence and deliver material, even though enough material is already in the loop.

Lack of information
- Even though information is constantly being sent and received at various operations within the flow, there is a great deal of uncertainties related to when an operation should start and when the material should be delivered to the next process, which in turn has an effect on the uncertainty of when material will arrive. This uncertainty can be found in several areas such as; (1) Forklift 1, who sometimes delivers only one rack to the moving floor or supplies only one new rack with material from the Incoming Goods Area. (2) the Sequencer might have to wait due to that sequenced racks are not picked up, which can result in the operator starting to feel stressed, due to that the queue of sequencing orders increases. (3) when material is not being supplied to the Platforms in time, two full racks of sequenced side panels might be standing at the IT Torget, while two empty racks are awaiting replenishment at the platform. This might result in the operators at the Platform starting to wonder where the material is and whether this situation might lead to a stop of the production line.
- Digital communication is used in the flow, where barcodes and automatic triggers send signals to designated operations, containing information of which material is required and in what sequence. The flow however uses several different subsystems that are only partly interconnected. When information is required from one of the stations, there is no overall system that can be accessed to withdraw data. Instead each process needs to be individually investigated. For logistics management, this creates an additional challenge of knowing where to find the required information.

Lack of reliable data
- When operators were asked to describe their working process and their responsibilities, they often described the standard process. Even though this process was mostly correctly described, this did not always reflect the working procedure. The operators explained that often they have some freedom on how to conduct their work and in which order. This shows that the standard and planned procedure does not always reflect the working process. This might result in that changes and improvements are based on information which is not reliable.
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- At the Production Site, there was an impression that there were only 12 racks with side panels in the internal loop, when in fact there were 20 (excluding the Empty rack buffer).
- When a deviation of side panels is reported to the deviation list, Bristlistan, there is a challenge of identifying the root cause of the deviation as well as to assign a department ownership over the incident.
- Parts of the flow are not being measured. To some of the operations in the flow, the only data available is the data according to the standardized process, but historical or real-time data is not collected. This became evident when the transports between the Logistic Centre and Production Site was under investigation, where the planned schedule was the only information available, but did not reflect the observed transport schedule.

Processes reliant on individuals

- At the Logistic Centre, several working tasks of Forklift 1 are influenced by the operator’s individual judgment and prioritization. The specific order and sequence of the side panels is defined by the signal that the operator receives, but the timing of conducting the tasks or how to prioritize the orders is based on the operator. This led to a truck departure from the Logistic Centre without any side panels, due to the fact that the forklift operator had not managed to deliver the material from the Sequencing station in time.
- The Forklift 1 operator is responsible to note down on a piece of paper, which compartment at the Sequencing stations buffer every painted side panel has been supplied to. This manual process is reliant on the individual operators’ ability to keep track of where material is being stored, and to make sure that the paper is kept in a good condition and readable for the sequencing operator.
- At the sequencing station, visual controls of comparing the requested article number to the article number on the specific side panel are used. This is to ensure that the correct side panels are picked and placed in the right compartment in the rack. However, the data from the deviation report list, Bristlistan, shows that the wrong sequencing, picking and lost side panels account for 10.2% of the reported incidents. This data might indicate that the visual control of the sequencing and picking is too reliant on the individual.
- The truck transports between the two sites have a planned schedule of when to arrive and departure from each station. However, this process is unstable based on that the average arrival frequency at the Production Site is 23:17 min and has a high standard deviation, as well as a wide spread between min/max. This indicates that the planned schedule is not followed and that the process instead relies on the truck driver’s individual judgement of when to arrive and departure.
4.5 Framework for the study

In Table 12 the findings and conclusions, of the 13 articles that are presented in chapter 2.5, are summarized to show the six most supported correlations between RTLS and JIT management.

Table 12 - Summary of the theoretical framework

<table>
<thead>
<tr>
<th>Article</th>
<th>Material flow &amp; Stock control</th>
<th>Information transparency</th>
<th>Track &amp; Trace</th>
<th>Waste elimination</th>
<th>Reliable data</th>
<th>Risk Reduction</th>
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<td>(6)</td>
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<td>10</td>
<td>7</td>
<td>5</td>
<td>4</td>
<td>2</td>
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</table>

These six areas are defined to build a framework, where the most frequently discussed potentials of RTLS, in relation to improving JIT challenges are presented. This is used in chapter 5.1 to evaluate how RTLS could counteract the challenges presented in the previous subachapters.

**Material Flow and Stock Control:**

Almost all studied articles emphasise the increased material flow and stock control within JIT management as a potential benefit of using a RTLS. In relation to the framework for this thesis, this criterion will be related to overall improvements and rationalizations of JIT material flows and the reduction and control of WIP inventory within them.

**Information Transparency:**

The advantage of increasing the information transparency has also been stressed by a majority of the authors. This criterion relates to the ability of RTLS to visualize relevant information and the possibility of sharing information across different departments and teams, instead of keeping decentralized knowledge bases. This centralized information accessibility of RTLS allows for the right information to be accessible by the right people at the right time.
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**Track and Trace:**
The criterion of track and trace is, as opposed to the material flow and stock control, related to the possibility of accessing information on the location and movements of the physical objects within a flow. This also allows for a rationalized identification of goods and improved sequencing and picking activities.

**Waste Elimination:**
The potential of RTLS in aiding in the elimination of wastes has also been highlighted within several of the studied articles. While most authors relate this to waste elimination in general, the literature review revealed that the data a RTLS provides can be especially helpful in the reduction of inventory, transportation and waiting times.

**Reliable Data:**
Easily accessible and reliable data, that can additionally be backed up by historical data, has also been pointed out as an advantage of RTLS by several authors. This has been especially highlighted as allowing managers to make more informed decisions.

**Reduce Risks:**
Within two of the articles, the reduction of risks by applying a RTLS were pointed out. Therein the reduction of risks was on the one hand related to minimizing human errors and mistakes and on the other hand to the possibility of sharing risks among supply chain partners, which decreases the bullwhip effect and the risk of investment for the implementation of the system.

As presented in Table 12 Material Flow and Stock Control is the most supported correlation between RTLS and JIT, while Reducing Risks is only mentioned twice. This does however not mean that RTLS does not provide the user with the possibility of reducing risks. It rather shows that most research associate RTLS with material flow and stock control.
5 Discussion and conclusions

This chapter of the thesis is separated into three parts. First, the findings of the thesis are discussed and examined in relation to the theoretical framework that was presented in chapter 2. In the second part the research approach and the achievement of the studies purpose are critically assessed. Within the last part of this chapter the final conclusions are drawn, and future research is suggested.

5.1 Discussion of findings

In this chapter, both the categorized findings from the identified challenges related to logistics management and the material flow, are evaluated in relation to the framework, which was presented in chapter 4.5. By evaluating both the identified challenges related to logistics management and a specific material flow, both a practical and managerial evaluation of the framework was made possible. The chapter first presents the two evaluations of the framework, which is followed by a discussion of the framework’s usability and functionality.

5.1.1 Evaluation of logistics management in correlation with framework

In this part, the potentials of RTLS are evaluated in relation to the identified general logistics management challenges (see chapter 4.1). The evaluation of each category is explained and discussed, before at the end of the subchapter, a visual summary of the discussion is presented in a matrix structure, showing the correlation between the identified challenges within logistics management and the framework (see Table 13).

High Complexity and space constraints

The identified challenges related to high complexity and space constraints, supports the principles of the system theory presented by Hull (2011), where all systems in an organization is interconnected and effected by changes. In a system consisting of a large number of parts, it can be argued that a resulting consequence is an increased need for control over the logistic processes. By tagging assets in the plant, using a RTLS and monitor the movements, companies can gain a larger control over the products and/or components within the plant (Haddud, et al., 2015), wherein the real-time tracking will allow managers to access information of the shop floor status on demand (Dai, et al., 2012), which in turn can provide data to enable the company to become Leaner by eliminating waste related to material flows, WIP and inventories (Zelbst, et al., 2014).

Due to the fact that a RTLS is constantly monitoring and storing data of the logistic movements in the plant, the RTLS could be integrated with an additional software that could select or suggest various actions to take, dependent on the current status at the plant (Chen & Tu, 2009). For Scania, this could mean that that certain decisions could be handled by the RTLS and thus limit the complexity related to which action to take in specific situations, for example to prioritize material deliveries if a warning of material shortage is triggered. In a system with rigorous cycle times and a strong dependency on material arriving in the right time and at the right place, the RTLS could handle potential threats to the material supply, before an actual problem occurs and at the same
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time allow managers to respond faster to deviations in the logistics if an incident escalates (Chen & Tu, 2009). This means that the system could foresee where forklifts and trains will be and in what point of time, and select appropriate actions, before a late supply to e.g. the line occurs.

The ability to track and trace assets also means that a RTLS can assist managers to detect bottlenecks (Chongwatpol & Sharda, 2013). This means that vital data of which transport is causing critical delays, can be identified and improved. Which in turn could have a positive effect on the material logistics as a whole.

**Time Constraints**

There are both internal and external factors that effects in which sequence the cabs are to be produced. This shows that the planning of sequencing the cabs to the line is a complex task and requires a lot of information from several sources. In order to increase the information accessibility and transparency related to material shortage and quality issues of received goods from suppliers, the RTLS could be implemented in the supply chain. This would allow Scania and its suppliers to increase the information sharing and transparency, and provide vital information of when material was shipped, where it is now and when the delivery will arrive (Huang, et al., 2010). If the planners of the sequence of the line have access to such information, more informed decisions of the sequencing can be made, which could rationalize the planning by knowing that key factor of when material will arrive (Li & Fan, 2008). As a result, plans can be made for upcoming sequences. This, by knowing that the cabs that were not allowed to enter the line in time X, will instead be introduced in time Y. By connecting the RTLS to Simas (Scania’s ERP system), the accessibility to information internally at Scania could increase (Zelbst, et al., 2014) and proved personal at the line with an information of what sequence is to come. This could mean that if cabs that require more time at assembly, or if several cabs requiring low frequency components, are sequenced close to each other, team leaders could redirect employees or start to support the line, before a problem occurs (Rafique, et al., 2016).

One of the key functionalities of the RTLS are related to tracking and tracing material. If tags were installed to monitor the low frequency components, the planners could see the inventory status as the line (Tabanli & Ertay, 2013). This could mean that if only a few components are at the line, the risk for a supply shortage increases. If the planner could see this information before, the logistics department could be informed before the fixed sequence on the line was final, which in turn could provide them with a larger window of supplying material to the line in time.

**Lack of transparency**

A central aspect often discussed in literature is RTLS capability of increasing the transparency and information sharing within the plants. In Scania Oskarshamn, areas where a lack of information was evident, were often described as “black holes”. These areas create additional challenges related to both daily operations, as well as for logistics development. In the arrival area at the production site (Canopy), a RTLS could enable Scania to identify each specific location of assets (Rafique, et al., 2016), as well as to
identify which article every material carrier contains (Patti & Narsing, 2011). In this area the forklift operators only unload and load the trucks, resulting in that the material is not registered in the system, until it is being stored at the automated high bay storage. This calls for a solution where suppliers need to be included in the RTLS solution. By partner up with suppliers, the tags can be installed before shipment to Scania, which would allow Scania to automatically receive delivery information and keep track of the material. By partnering up with suppliers, additional benefits such as shared costs of tags, technical competences and risks can be gained (Huang, et al., 2010). This suggests that by solving the problem of the blackhole at the arrival station at Scania, positive synergetic effects can also be achieved for both Scania and its suppliers (Li & Fan, 2008). If we assume that material arriving from suppliers and the Logistic Centre are tagged using RTLS, the possibilities of tracking and tracing material internally in the plant is possible. Such system could provide information to operators in the workshop that replenishment orders are received, and inform them when the supply will arrive (Su, et al., 2009), and provide managers with vital information to improve the plants layouts and internal logistic flows (Chen & Tu, 2009). Hence, the RTLS could make out the fundament of information on which buffers, flows, transports and cycles can be improved.

**Lack of Communication / Data Connections**

The lack of communication and data connections at Scania was observable within different characteristics of the general logistics management and could in various aspects be bridged by the introduction of an RTLS. Within several of the articles, that were used for the creation of the framework, the ability of RTLS to provide data that will improve material flow and stock control were emphasized (e.g. Powell & Skjelstad, 2012; Su, et al., 2009; Dai, et al., 2012; Zelbst, et al., 2014; Tabanli & Ertay, 2013). This would address the lack of information regarding the consumption of the material stock at the line and allow the logistics and production managers to rationalize the resupply of the material.

The centralized availability of information a RTLS provides (Li & Fan, 2008) would also allow the different departments to be aware of their status in relation to the consumption at the line. It could furthermore be used for a more rational planning of transports (Li & Fan, 2008) by making it possible to prioritize some material transports over others, when bottlenecks occur (Chongwatpol & Sharda, 2013). This is also connected to the need of levelling the retrieval from the automated high bay storage to avoid peak times.

It was furthermore pointed out by several authors, that RTLS allows for an overall improved control of material flows (e.g. Powell & Skjelstad, 2012; Chen & Tu, 2009), which would provide a more effective and transparent planning of the resupply of material to the line, than the currently often used method of limiting racks in the supply chain loop.
JIT / Improvement focus

Even though there is a strong focus on productivity at Scania Oskarshamn, both on an aggregated level where the overall output is measured and on an operational level where KPIs are kept over e.g. the number of pallets delivered in an hour, it is important not to forget that efficiency and productivity are interconnected. Hence, it can be argued that the productivity might be negatively affected, if the efficiency of the production processes is neglected. A crucial aspect is therefore to ensure the commitment of managers to also emphasize on efficiency improvements, which in turn could have a positive effect on productivity. Dai et al. (2012) conclude from their research that one of the key factors for a successful implementation of RTLS, was the increased commitment and engagement that the system created for managers within the organization, which had a positive effect on employees view of change and their determination for success. RTLS could therefore not only be used as a source for information of tracking and tracing assets, but also create a broader interest of efficiency improvements and enable collaborative teamwork where employees can share experiences and knowledge throughout the processes (Dai, et al., 2012).

Taking a broader perspective, the RTLS could allow the internal logistics to respond faster to events at the production line (Chen & Tu, 2009), which could prevent production stops or late assemblies of cabs in a later stage. This in combination with RTLS’s abilities of tracking and tracing assets in real-time, could allow for improvements of internal lead times between operations and stations within the material flows (Rafique, et al., 2016) and increase the companies’ delivery responsiveness of internal material (Zelbst, et al., 2014). Hence, by responding faster to changes and create improvements of the logistics efficiency, the productivity could be increased as well. This in turn shines a light on the importance of not only consider improvements to productivity, but also include the efficiency of operations and processes.

Lack of reliable data

In the framework, two articles are emphasizing of a RTLS correlation with reliable data. However, in this case there is an evident lack of reliable data as well as challenges related to accessing information. This stresses the importance of not only considering the aspects of reliable data, but also focus on how to increase the accessibility to information. Important to remember is that when the logistics managers express challenges in relation to reliable data, it can be argued that the challenges are not directed to any specific process or flow, but rather a general challenge concerning several processes of logistics.

Due to that a RTLS constantly is monitoring, collecting and storing data of the assets (Chen & Tu, 2009), historical data of logistic processes can be easily accessed by managers. This results in two main benefits, (1) the database of information provides access to a large amount of data (Su, et al., 2009), which have a positive effect on the reliability of the data, and (2) the information can be accessed on demand (Rafique, et al., 2016), which limits the need of time consuming manual data collection techniques being used. For the logistics development department, this would mean that they could focus on their core responsibilities of developing improved material flows, rather than searching
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and collecting information. This source of historical information and data of assets could rationalize the process of identifying root causes of deviations, or to identify bottlenecks within the flow (Chongwatpol & Sharda, 2013). This would have a positive impact on Scania’s ability to assign ownerships to deviations and to respond faster to situations that might cause a production stop (Chen & Tu, 2009), which in turn implies that deviations are detected within the material flow and not after the problem have reached the lines. In addition to the technical benefits of the system, a RTLS could also enable a positive atmosphere where people positively embrace changes (Dai, et al., 2012), maybe based on that a RTLS increases transparency and decreases uncertainties, which could minimize the perceived stress of individuals. By knowing why, where and how things happens in the flow, the amount of subjective opinions could be limited, and instead the focus could be directed towards identifying solutions.

Employee Attitude

The detected challenges within the logistics management regarding employee attitude were mainly related to problems caused by operators lacking an understanding of how their station contributes to the overall material flow and how it is interconnected to the other stations within the flow. Kouri et al. (2008) as well as Su et al. (2009) point out that e-Kanbans increase the information system and visibility throughout the production system. By applying those, it can therefore be argued for the operators being more aware of their status in relation to the overall flow, which would rationalize both the flow as well the reaction of operators to for instance shortages of empty racks, because they would gain a better understanding of what the cause of the shortage is. Dai et al (2012) and Zelbst et al. (2014) also point out that knowledge and information sharing throughout the process is a vital success factor for the implementation and utilization of RTLS, which further underlines the importance of making the information of the current status of the material deliveries, available at the different stations within the process.

Another challenge within the general logistics management, was that the farther away a station is from the line, the lower the importance of keeping to the takt of the line is perceived. By giving the logistic operators the possibility of seeing the actual demand at the line, that RTLS could provide (Dai, et al., 2012) this could be counteracted, and response times could be improved (Chen & Tu, 2009).

Rafique, et al. (2016) also call attention to the possibility of RTLS to provide managers with the necessary information to improve employee management, which is related to the challenge of employees being reluctant to change processes. RTLS would provide change managers with the reliable data required to convince employees of the necessities of change and would furthermore allow them to more accurately predict the outcome of the change, which could help in easing the minds of affected operators, that the change will not cause problems in the material flow.

Dai et al. (2012) do, however, also point out that the installation of a RTLS will require employees to be educated in the new technology, which could then also go along with
educating them in how this information affects their work and gain a better understanding of the overall interconnections of the flow.

The table below presents a visual summary of the relationship between the potentials of RTLS from the framework (see chapter 4.5) and the identified general logistics challenges of the case company. As can be seen in the matrix structure of Table 13 the general logistics management challenges, which represent the managerial aspect of logistics management for this study, most strongly correlate with the criteria of Material flow & Stock control and Information Transparency, while the criteria of Waste Elimination and Risk Reduction, only seldom affect the general logistics challenges. This will be further discussed in chapter 5.2.1.

Table 13 - Evaluation of general logistics challenges in relation to the framework

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<thead>
<tr>
<th></th>
<th>Material flow &amp; stock control</th>
<th>Information Transparency</th>
<th>Track &amp; trace</th>
<th>Waste Elimination</th>
<th>Reliable data</th>
<th>Reduce risks</th>
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5.1.2 Evaluation of the findings from the flow in correlation with framework

This section follows the same structure as the previous subchapter, with the evaluation being focused on the correlation of the categorized findings from the studied material flow, which is evaluated in relation to the framework of RTLS and its potential to improve JIT flows. These discussions are then again visualized in a matrix structure (see Table 14).

Complex logistic structure

Organizations can be viewed as an interconnected system consisting of several subsystems (Zelbst, et al., 2014), where a slight change in one area of the system might have severe consequences to other operations (Hull, 2011). This underlines the importance of having a wholistic view and identifying interconnections between operations within a flow, to avoid creating new or larger problems elsewhere in the flow. Li and Fan (2008) studied how the value chain could gain positive effects from having access to real-time data of tracking and tracing from the material in flow. They outline that this
information allowed both the suppliers and customers within the flow to improve the planning of deliveries as well as to rationalize the transport. This shows that within the studied flow at Scania, the supplier (focal operation in the flow) and the customer (next operation in the flow) could gain a lot from knowing where material is located and when deliveries should be performed. This information could be used to evaluate whether the side panel flow is an overall bottleneck in the flow, or if correlating flows are limiting the ability to deliver material (Chongwatpol & Sharda, 2013). This also requires that information is easily accessible throughout the flow (Dai, et al., 2012), where a central aspect for success is to integrate the system to the company’s ERP system, to avoid islands of information (Zelbst, et al., 2014). Hence, a RTLS could provide Scania with vital information related to understanding the correlation between flows, and to identify root causes to the high variation of the waiting times. In addition, the large amount of historical data over the monitored processes would enhance the reliability of the data and allow for more informed decision making, where decisions are based on facts rather than subjective impressions (Chen & Tu, 2009).

**Pull strategy with partial push material flow**

When material is pushed within a flow and creates additional inventory, more assets are tied up in material (Li & Fan, 2008), which in turn has an effect on the cash flow (Khojasteh, 2016). In the literature for the theoretical framework (see chapter 2.5), several authors discuss how a RTLS could enable the use of e-Kanbans and thus improve JIT flows (e.g. Patti & Narsing, 2011; Su et al., 2009; Kouri et al., 2008 and Chen & Tu, 2009). The e-Kanban could provide an additional dimension of information transparency which is considered to be a cornerstone of a successful JIT flow (Kouri, et al., 2008). The RTLS could enable that signals are automatically triggered by downstream processes, without any manual work (Patti & Narsing, 2011). This would create an automatic pull system, which is always steered by the downstream processes, and ultimately controlled by the consumption of material at the production line. By implementing an e-Kanban, rational and balanced JIT flows can be created (Su, et al., 2009), which according to Zelbst et al. (2014) could allow for reduced inventories, material handling and WIP.

Hence, if a RTLS was used with an integrated e-Kanban solution in the flow of side panels:

- Forklift 1 would no longer push material to the buffers at the Sequencing Station, nor would the Forklift 1 operator have to wait until two pick-up signals were sent from the sequencing operator, but instead one signal could be sent once two racks with sequenced side panels were ready for pick-up.
- At the Sequencing station, the operator would know when to start sequencing and when material needs to be delivered, based on a signal sent from e.g. the location of the transport trucks once they passed a defined location. This would have a direct impact on the Sequencing Stations ability to introduce more material into the flow.
- Since an e-Kanban would ensure that material is being pulled from the Logistic Centre, there would be an increased control over the material in the Inbound buffer (Canopy), since only material would arrive after a need was triggered.
Discussion and conclusions

Lack of information
The lack of information within the studied flow was often related to uncertainties of when exactly the material will arrive at, or should depart from, a specific station, and the consequences this has on the operators and the overall flow. The ability of tracking and tracing assets allows for the rationalization of shipping and receiving processes (Powell & Skjelstad, 2012), which would minimize the uncertainties within the studied flow. The issue of operators feeling stressed or worried, could also be counteracted by providing them with reliable data of when material will be delivered (Rafique, et al., 2016).

One of the biggest issues within the information management of the flow, is that data is captured in different subsystems, that are only partly or not at all interconnected. With the introduction of a RTLS, the information and data sharing capabilities become a crucial factor, which stresses the importance of interconnecting the subsystems and RTLS to an information sharing platform (e.g. ERP) (Zelbst, et al., 2014). By having one information platform, both logistics- and production managers could withdraw necessary information from a centralized system on demand, which could result in the improvement of the inventory- and production management and shorten lead times (Rafique, et al., 2016).

Lack of reliable data
Within the studied flow, it became evident that the known and communicated standard processes, often do not reflect the actual working procedure on the shop floor. Managers are therefore risking to basing their decisions and change actions on information, that is not reliable and often based on subjective impressions, which do not necessarily reflect the actual flow. The working procedures are also often effected by the individual operators’ judgement, which can result in the process working fine while one operator is manning the station, while it is not when another is performing the tasks, which further decreases the reliability of the standard processes. RTLS would decrease this risk of human errors (Su, et al., 2009), which would increase the reliability of the flow and it could provide managers with the right information to make more informed decisions (Chen & Tu, 2009).

The analysis of the flow also revealed that there are parts of the flow, on which no historical or real-time data is available. RTLS could provide the company with the on-demand information access to improve the overall management of the flow and shorten lead times (Rafique, et al., 2016). Kouri et al. (2008) also point out the possibility of including a support feature for continuous improvement in the RTLS, which could help the company in identifying the root cause of deviations and ultimately reduce wastes within the flow.

Processes reliant on individuals
The detected challenges within the flow that are related to processes being reliant upon individuals’ performance, motivation and judgement could be minimized by the potentials of RTLS to reduce risks, track and trace material and provide reliable data. As Su et al. (2009) point out the risk of mistakes by individuals can be decreased by the use
RTLS applications, as for instance the individual judgement regarding the prioritization of the Forklift 1 tasks. The possibility of tracking and tracing material would improve the efficiency of the kitting and sequencing of material (Powell & Skjelstad, 2012) which would improve the working structure at the sequencing station. The tracking and tracing of material would ensure that the processes no longer have to rely on visual controls by the operator, which would decrease the amount of deviations reported due to wrong sequencing and picking. This is also supported by the finding of Patti & Narsing (2011) that RTLS technologies can rationalize the identification of goods, which would make the process more reliable by making manual tracking like noting down the location of a part on a piece of paper as done at the sequencing buffer, unnecessary.

The reliable data a RTLS could provide would also rationalize the planning of transportations (Li & Fan, 2008), by allowing the company to ensure planned schedules (as with the trucks between the logistic center and the production site) are followed more dependently.

Table 14 presents a visual summary of the relationship between the potentials of RTLS from the framework (see chapter 4.5) and the identified logistics challenges within the material flow. In the matrix structure it becomes evident that the operational logistics challenges, which are represented within this study by the findings of the material flow, are rather evenly addressed by all the criteria of the framework. This will be further discussed in chapter 5.2.1.

Table 14 - Evaluation of flow findings in relation to the framework

<table>
<thead>
<tr>
<th></th>
<th>Material flow &amp; stock control</th>
<th>Information Transparency</th>
<th>Track &amp; trace</th>
<th>Waste Elimination</th>
<th>Reliable data</th>
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<tr>
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</table>

5.2 Discussion of the framework

5.2.1 Insights from the framework
As a general insight from the previous two subchapters, it can be noticed that many of the challenges of the logistics management within the studied flow, as well as the gen-
Discussion and conclusions

eral logistics management challenges at the focal company, would be resolved or counteracted by the benefits a RTLS in relation to JIT could provide. The visual overview of the correlation within Table 13 and Table 14 shows that all of the identified criteria of improving JIT by the introduction of a RTLS find an application within both the operational level, as was shown within the evaluation of RTLS on the studied flow (chapter 5.1.2), and the executive level of logistics, as was presented within the evaluation of RTLS on the general logistics management (chapter 5.1.1). Contrasting Table 13 and Table 14, does make it evident that the two levels of logistics management require different aspects of RTLS.

While the study of the flow in relation to the potential benefits of RTLS shows a wide coverage of all the identified criteria, the executive outlook of the general logistics management shows an emphasis on the improvements of material flow and stock control, as well as on the information transparency. Looking at this from a logical standpoint this makes sense, because the core responsibility of the logistics management is to develop efficient flows. While the operational level maintains the efficiency designed by the executive level and therefore requires the more granulated level of RTLS, as for instance the identification of goods. Because of this, it can be argued that RTLS allows a decentralization of information accessibility, because the information required for the day-to-day management of the flows becomes available on the operational level.

Another noticeable aspect of the two tables 13 and 14, is that the aspect of risk reduction is only marginally covered on the managerial level. An explanation for that could be that the managerial level includes the reduction of risk in the increased control over the material flow, where instead the studied flow provided findings that directly reduced risks related to e.g. human errors.

The factor of eliminating waste within the flow, was only rarely mentioned as addressing the challenges, both on the operational-, as well as on the managerial level, which could be seen as a strange finding, since the main aim of JIT is to eliminate waste within material and production flows. It can however be argued, that any improvements in efficiency would be based upon the elimination of waste, which would mean that this aspect is addressed by all the other attributes of RTLS. Furthermore, the elimination of waste on the managerial level should also be highlighted, since the easy access of reliable data allows managers and project leaders to focus upon the core responsibility of developing efficient flows, instead of searching for information.

In summary, it can be argued that a RTLS, has the potential of addressing the identified challenges and improve the company’s logistics management. Nevertheless, the question may arise whether a RTLS is the best solution to counteract the identified challenges, or if another simpler solution could be used.

5.2.2 Restraints of the framework

Due to that the framework (see chapter 4.5) does not take challenges related to the implementation of RTLS in to consideration, the following discussion reflects highlighted concerns that could cause barriers in a RTLS ability to enhance its potential in logistics management:
Discussion and conclusions

Dai et al (2012) referred to the resistance of employees as one of the biggest challenges within the implementation of RTLS. While most of the interviewed employees from the focal company, seemed to embrace the potential benefits of RTLS, one of the main findings within the general logistics management was related to the attitude of employees being focused upon not disturbing the status quo, in order to reduce the risk of stopping the line. This challenge could therefore provide a roadblock to a RTLS unfolding its full potential, because the employees might embrace the increased transparency, but might be reluctant to change their working procedure accordingly.

Another challenge outlined by Dai et al (2012) is related to the technology of RTLS. The fast development and changes of technologies create a risk that companies need to take into consideration when evaluating RTLS. While the framework showed that the implementation of a RTLS can come with a lot of potential benefits, the question remains for practitioners, if they are investing in a technology that will be outdated in a short amount of time, especially in front of the developments of the Internet of Things and Industry 4.0. The risks related to rapid development of technology also relates to the issue of battery capabilities that Lohan and Singh (2017) highlight, since more advanced technologies like for instance BT-LE would decrease the amount of maintenance of battery changes required in a RTLS, but these technologies are less tested. The consideration of battery life-time stressed by Lohan and Singh (2017) also needs to be reflected upon, in relation to the sustainability of a RTLS. While RTLS provides the possibility of increasing the efficiency of material flows, which can have a positive impact upon the ecological footprint of a company, by for instance decreasing the amount of transports required, the ecological footprint of a company could also be negatively affected by having to exchange batteries at a high frequency.

The challenge of interferences from the environment, which was highlighted by Fisher and Monahan (2012), also has an influence on the decision of companies to implement an RTLS and especially affects the choice of technology.

Since a RTLS uses wireless technologies, the issue of cyber security provides another risk related to RTLS, since the two types of attacks presented by Hinai and Singh (2017) can both harm the competitiveness of a company. Passive attacks furthermore present a risk for the ethical obligation of a company to protect their employees’ privacy. It therefore needs to be taken into account that the implementation of a RTLS should go along with an evaluation and possible update of the cyber security system of the company.

The ethical aspect of collecting real-time data on the movement of materials and resources needs to be considered in general, in order to contemplate the introduction of a RTLS. Even if the company can protect the RTLS data from outside attacks, the system provides the possibility of monitoring employees movements and work, either directly by tracking the operators or indirectly by tracking transport devices like forklifts or the movement of material. This can be a concern in relation to the individual worker’s privacy, as well as in relation to the possibility of people with access to the system abusing the information, e.g. for the evaluation of operators’ performances.
Discussion and conclusions

5.3 Discussion of method

The purpose of this thesis was to:

*Investigate how the potentials of Real Time Location Systems could be utilized within logistics management, by researching the positive impacts of RTLS on Just-In-time management.*

The purpose of the study has been achieved by investigating how the identified challenges of (1) one specific material flow, and (2) general challenges of logistics management, could be improved by the potential of a RTLS. By analysing the theoretical framework (see chapter 4.5) from two angles, one practical (the flow of side panels) and one managerial (general challenges of logistics management), and by using various data collection techniques, a triangulation of the framework was achieved. The triangulation of the phenomena studied, as well as the evaluation of the framework, strengthens the study’s results and increases the studies reliability and validity. This allows the researchers to support Gladysz and Buczaki (2018) statement that there is a strong support for RLTS to enable improvements of the JIT principles of Lean.

Even though a triangulation was used for the evaluation of the framework, the case study method is often limited to what extent the results are generalizable.

*RQ1: What are the potential benefits of a RTLS in relation to its effect on JIT management?*

The first research question was answered by the creation of the theoretical framework in chapter 2.5, where literature searches were conducted to identify what positive impacts RTLS could have on JIT management. The literature review by Gladysz and Buczaki (2018) was identified, which allowed the researchers to take a stand from a thorough investigation of the RTLS impact on JIT. This created a solid foundation for the framework, where all articles included were reviewed and considered valuable by additional researchers. However, this approach also had some limitations, where arguably other literature might have resulted in a different framework, which in turn could have affected the results of the study.

*RQ2: How could the logistics management at a manufacturing company conceptually be improved by utilizing the potentials of RTLS in correlation to Just-In-Time?*

The second research question was answered in chapter 5.1, by evaluating how the identified challenges from the side panel flow and the general challenges of logistics management, could be improved by an RTLS. The two dimensions of evaluation allowed the researchers the investigate the phenomena of a RTLS impact on JIT from two angles, which strengthened the study’s validity. Since all data was collected from only one company, the results might have been different if the framework was evaluated at more cases.
Throughout the study various data collection techniques were used to triangulate the empirical findings, which had a positive effect on the study’s reliability. However, the time constraints of the thesis were considered a challenge, which had a negative impact on the amount of data collected. This in combination with the limited amount of historical data available from local systems, contributed to the researchers being reliant on additional information from interviews and observations, where there might be a risk of biased empirical findings. It can therefore not be ignored that, if the study would have been conducted over a longer period of time, the reliability of the study could have been increased.

The reliability can also be of concern in relation to the data collection of the study. Taking time measurements of various operations arguably holds the risk of affecting the operator’s performance, in comparison to their behaviour when no measurements are taken. When measuring operations were individuals work, there is also a concern of ethical aspects that should be considered. On this basis, no names are presented in the report, and all of the collected data has been anonymized where all measures from various days are complied, to present an overall average of each operation.

In relation to the validity of the study, it is important to highlight the risk of the researchers being biased. Based on that the purpose of the thesis was to explore how the potential of RTLS could affect JIT management, this might have had an effect on what challenges and deviation were identified and considered to be of concern. This was however accounted for by triangulating the evaluation of the framework.

In retrospect, a more suitable method to evaluate how a RTLS positively could impact the JIT management, would be to install the system and evaluate how the logistic flows performed before, in relation to after the installation. However, for this study this option was not possible due to time- and financial constraints.

### 5.4 Conclusions

This study has investigated how the potential of RTLS could be utilized within logistics management, by researching the positive effects RTLS could have on Lean’s JIT management. The study shows that all the identified challenges at the case company, both on the operational level (the studied flow) as well as on the managerial level (general challenges of logistics management), could potentially be counteracted by the implementation of a RTLS. In conclusion, this study therefore supports the academic community’s understanding of RTLS’s positive impact on logistics management.

In addition to RTLS’s direct potential of providing data for the improvements of logistic flows, where operators e.g. can be provided with information that allows them to know when to conduct certain operations, which in turn decreases variations of various operations within material flows, it was identified that the RTLS could counteract several challenges on a managerial level as well. This became evident with the fact that most of the general challenges of logistics management were either related to information accessibility and transparency or to the improvement of complex flows, wherein several aspects need to be considered due to the interconnectivity of flows in the system. This could indicate that on a managerial level, the easy access to information of historical
data from several sources in the plant, could potentially rationalize the process of identifying logistic flows that require improvement and increase the manager’s ability to take several aspects into consideration. In contrast to manually collecting data over a period of time, which could have a negative impact on the reliability of the data, a RTLS could ultimately allow logistics developers to focus on their core responsibility of developing new and improved logistic flows. This highlights a central aspect of an additional potential of RTLS, where future research is suggested to further investigate the effects RTLS could have on a managerial level. This broadened perspective of RTLS potential could arguably be the missing link to attract organizations to invest in the technology and enable the next level of process optimization in logistics management.
6 References


References


References


Shaohua, H. et al., 2017. *A Real-time Location System Based on RFID and UWB for Digital Manufacturing Workshop*. China, Procedia CIRP.


7 Appendices

7.1 Appendix 1 (Exploratory) Interview questions

Q1: Could you please present yourself and elaborate on your responsibilities at Scania?

Q2: How would you describe Scania internal logistic flows in relation to Just In Time and the use of Lean support tools to achieve a continues flow within the production?
   - In your opinion, what is the biggest challenge within the internal logistics at Scania, Oskarshamn?
   - Bottlenecks within your internal logistics?

Q3: Can you please elaborate on the JIT management within the Scania Oskarshamn Assembly?
   - How do you ensure pull-production?
   - Do you have a Kanban System in place and how is it managed?
   - Where do you think the most deviations occur from the standard/the optimal state, and what are they?
   - Do you measure KPIs on “internal delivery” and if so, what are they?
   - Do you measure KPIs on “inventory– and service levels” and what are they, how are they calculated?
   - How are the KPIs cascaded within the assembly? Where do you have the worst results?

Q4: Does the production line get a confirmation when requested material is on its way?

Q5: Do you have any workarounds to ensure the line does not stop?
   - What are they and how often do they occur?
   - Informal routines?

Q6: How do you work with analysis and improvements of logistic flow?
   - How is the data collected?
   - Which criteria do you use?

Q7: How do you currently work with tracking and tracing of assets?
   - Different systems - how are they interconnected?
   - How many resources are dedicated for tracking and tracing of e.g. material and assets?

Q8: Do material/pallets/carriers get misplaced?
   - What can the consequences be?
   - How do you minimize this risk?
Q9: How are the return flows of carriers managed?

Q10: How are the tools and machines managed, that are used in production?
   - Specific tools for certain tasks?
   - How do you ensure tools does not get used elsewhere?
   - Do employees spend a lot of time searching for the correct tool to use?

Q11: In your opinion, what should be the primary purpose of the introduction of a RTLS? (Reduction of inventory/ lead time/ waiting time/ tracking of conveyance within the production to find ways to optimize it (spaghetti diagram) /increase of utilization of assets – which assets? / Minimization of “lost” assets or material /minimization of theft/….)

Q12: Which flow do you suggest to be a suitable alternative for this study?
Appendices

7.2 Appendix 2  Reflective preparation questions for focus group

- What are the strengths within the logistic management / material flows at Scania Oskarshamn?
- What are the weaknesses / what is Scania Oskarshamn currently lacking in regard to its logistic management / material flows?
- What are the consequences of the weaknesses/ short-comings of the logistic management / material flows?
7.3 Appendix 3 Workshop Structure

Logistic management & material flows

Effects on material flows

Information required

Strengths

Weaknesses
Appendices

7.4 Appendix 4 Visualization of the Side Panel Flow

Legend:
- Supplier
- Assembly
- Paint Shop
- Cab Production Line
- Incoming Goods
- Storage
- Pallet Racking
- Storage
- Buffer at Sequencing Station
- Moving Floor
- Push Flow
- Pull Flow
- Electronic Information
- Platform Line
- IT Torget
- Canopy
- Logistic Center
- Production Site
- Inventory / Buffer
- Production Plan
- Forklift 1
- Forklift 2
- Forklift 3
- Forklift 4
- Forklift 5
- Train