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SCHOOL OF BUSINESS, ECONOMICS AND LAW

Master Thesis Project in Logistics and Transport Management

Inventory management of redundant components in a highly automated environment

A case study at a manufacturing company

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Abstract

SKF is a leading manufacturer of bearings, seals, lubrication systems, and condition monitoring systems. Since its beginning in 1907, the company has grown steadily, and now it serves clients in over 130 countries worldwide. The paper looks into a part of one factory in Sweden that has taken significant steps in the previous decade to become more data-driven and hence more automated. Following that, new issues within the factory arise. The objective of this research is to examine the management of redundant components in the studied area. The studied area acts, among other things, as a warehouse for these redundant components. Following the identification of common issues and bottlenecks, the goal is to determine what problems could be mitigated and how this could occur in order to improve the efficiency of the currently non-automated flow of redundant components, in the highly automated factory. The study was performed using both primary and secondary data. The primary data was mainly gathered using a qualitative approach, by conducting interviews. The secondary data is primarily displayed in the literature review and case description. The study indicates that there are many issues in the studied area of the factory, where some issues are more consistent among the respondents than others. These issues can in one way or another be connected to each other. Therefore, the suggestion for SKF would be to understand the connections and base their future decisions on them. The main findings imply that limiting the number of items in the studied area is the first countermeasure, which can be done by utilizing a technology or a formula that determines which components that in fact are redundant. In the future, the goal would be to decide whether a component is redundant or not even before it is transported to the studied area.

Keywords: *Automation, Inventory management, Redundant components, Materials flows, AGVs.*

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Gothenburg, May 29, 2023

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1. Introduction

This chapter presents the background with different areas that will be relevant for the study. Lean management, materials flows and automated guided vehicles are a part of these highlighted areas. Later on, a problem description is presented, which displays the challenges the case company is facing. Last but not least, the research questions are presented as well as the purpose and scope of the study.

1.1 Background

Over the decades, lean management for inventory has come to be linked with efficient inventory management. Nasim et al. (2016) note that lean inventory management differs significantly from conventional techniques since it begins with the notion that inventory should be seen as a liability and not an asset. The interpretation of lean production, according to Anđelković et al. (2016), now emphasizes continually raising customer expectations for value in addition to its character of reducing waste and costs. In a larger sense, it emphasizes improving performance levels and cutting back on or eliminating some tasks based on whether they offer value or not.

Additionally, according to Brunner and Rechberger (2016), materials flow describes the movement of raw materials, components, work-in-progress inventories, and finished goods through a system. When the materials flow is uneven and materials are stored or stopped in the middle of production, the company loses time, money, and resources. Excess inventory can result in longer lead times and defective products, and poor material flow might make it difficult for management to restock materials on time (Brunner & Rechberger, 2016). However, organizations that are able to connect their materials flow handling with information technology are also able to collect larger volumes of more meaningful and real-time data as well as evaluate and apply that data to make better and more educated decisions. This data-gathering, analysis, and decision-making process can result in considerable competitive advantages for a firm. This means that data and technology have been used to coordinate everything from customer orders to fulfillment, inventory management, labor, warehousing, transportation, and delivery (Chakma et al., 2019).

Consequently, manufacturing companies have become more and more automated during the last decades, to make the production and materials flows more efficient (Sabattini et al., 2015). With the advancement of logistics technology, Automated Guided Vehicles (AGVs) are currently utilized in modern autonomous warehouses because of their attributes of auto guidance, accurate positioning, optimal route, and safety. AGVs can appear in many different forms but the common primary objective is to move between different industrial stations in order to boost output, enhance automation, and lower labor costs in warehouses (Chakma et al., 2019).

At the same time, factories that are highly involved in rampaging automation and technical development do not have all the answers. An AGV could solve many problems and facilitate the factory, but it also creates new problems. For instance, AGVs desperately require adaptability, both in terms of the people handling them, and their working areas (Zuin et al., 2020). They often share space with human workers and hence, humans and AGVs need to be cooperative to minimize risks of accidents that could not have happened before the AGVs´ involvement (Berndtsson et al., 2018).

1.2 Problem description

The company SKF has several factories in Sweden, some of which are highly developed, in terms of technical solutions and automation. Along with the rising automatic solutions, new challenges need to be faced. This paper is investigating one of the factories in Sweden that during the last decade has taken big steps to become more data-driven, and hence has become more automated. Thereafter, new problems within the factory arise. Automation leads to new opportunities and more efficient solutions, for instance, machines can work twenty-four hours a day seven days a week (Ivanov & Webster, 2019). At the same time, the focus on automation can make it easy to miss problems or bottlenecks that are less connected to the automated processes.

Accordingly, it should be added that the paper investigates one certain part of a factory that consists of both automated and non-automated materials flows. The investigated area works both as the last station for final products, and as a warehouse for sub-components for their final products. Those components can simply be described as leftovers but will in this thesis be referred to as “Redundant components”.

The flow of final products is well divided among the workers, machines and AGVs, and is almost fully automated. Meanwhile, the redundant components lack this systemized view, and that flow would instead be described as non-automated. Hence, there are issues regarding how the components should be managed in the most efficient way, to not get stuck in the temporary warehouse for too long. It could be a question of responsibility, where it is not clear who is responsible for which part in this process, but first and foremost, it is a question of strategy, since it is unclear how the components should be managed in the most efficient way.

1.3 Purpose

The purpose of this report is to understand the issues and find corresponding solutions regarding deficient management of redundant components in order to achieve more efficient flows.

1.4 Research Questions

The research questions in accordance with the problem description and purpose become as follows:

RQ1

- What are the problems for the management of redundant components in the studied area?

RQ2

- How can the identified problems be opposed? (Short-term and long-term)

1.5 Scope

This study's delimitations can be narrowed down into three steps. Firstly, the study's aim of contributing to research in terms of understanding issues related to automated- and non-automated materials flows is achieved by evaluating “the basement” in one of SKF`s factories in Gothenburg. The basement will be further elaborated later, but can simply be described as the lowest floor in the investigated factory and it acts as a warehouse for

redundant components as well as final products. Secondly, the study does not attempt to create new technical solutions, in an already technical environment. Instead, the study tries to put the identified problems in relation to theoretical solutions. Lastly, the study is limited to investigating issues that in some way are related to the flow of redundant components. Thus, the study does not examine the automatic production in the factory, but only focuses on the materials flows.

2. Literature review and theoretical framework

The literature review is divided into three main headings, and an additional fourth heading which adapts the three initial headings into a theoretical framework . The first one, "How automation today can enhance decision-making", is fairly explanatory and describes different topics and essential terms for the research. The second one, "Humans working and collaborating with machines", is a segment that discusses the relationship between humans and consequences of automation. The last chapter with the title, "The importance of how inventories are managed", focuses on wastes, costs and actions related to lean management and making materials flows more efficiently managed.

2.1 How automation today can enhance decision-making

Ghobakhloo (2020) explains that in an ecosystem known as Industry 4.0, networked computers, intelligent machines, and smart materials interact with one another and the environment to communicate and eventually make decisions with little to no human intervention. The actual power of Industry 4.0 provides digital connectivity and information creation. The use of intelligent machinery and gadgets, as well as the digitization of business and manufacturing processes, may have a number of positive effects on waste reduction, resource efficiency, and production productivity. In turn, Zuin et al. (2020) mention that industries are becoming more and more automated as part of the fourth industrial revolution. The reason is to satisfy the demands of a constantly changing market. AGVs, which frequently collaborate closely with people in congested areas, are a commonly utilized and well-established option today. So, in addition to flexibility, safety is a key consideration for automatic handling systems (Zuin et al. 2020).

Zuin et al. (2020) explain further that AGV implementations are difficult because of constantly shifting layouts and the need for extreme adaptability. It must share floor space with other objects, such as human operators, whose trajectories are unpredictable, increasing the risk of collision in industrial situations. This makes it vital for the operators to be able to communicate directly with AGVs. Berndtsson et al. (2018) mean that in order to be more cautious of risks and be more aware, the use of analytics comes into play. Organizations can analyze what has happened in the past with the aid of descriptive analytics. A common illustration of a descriptive method for gathering and analyzing historical data is by the use of

data warehousing. With the aid of data mining techniques, predictive analytics assists organizations in identifying trends in their data that were previously unknown.

However, it is not sufficient to just gather data and use it to generate reports and dashboards. In order to realize how to properly use the data, it is critical that the organization has access to the proper type, high quality, and analytical expertise of the data (Berndtsson et al., 2018). Furthermore, Berndtsson et al. (2018) propose five crucial enabling aspects, including management, data, tools, structure, and decision process, to develop a data-driven culture and strategy. When mentioning a data driven culture, Valacich and Schneider (2018) explain that Business Intelligence (BI) and "Advanced analytics" are applications for decision support. BI tools give an understanding of what has happened, while advanced analytics tools provide an understanding of why it happened. Therefore, advanced analytics provide users the opportunity to build predictive models.

Moreover, the integration and evaluation of data in order to make an organization's decision-making process easier by transforming data into useful information is a general definition of BI (Tavera Romero et al., 2021; Ain et al., 2019). BI can be used in various technologies, but consistently has the aim of organizing and analyzing data to make it comprehensible and useful for decision-making in organizations. Thus, organizations with prosperous BI can have competitive advantages, in terms of better foundation for their decisions (Sharda et al., 2014).

Furthermore, Valacich and Schneider (2018) state that, although BI or advanced analytics applications can be valuable detached, their convergence increases organizations´ decision-making process. Thus, both Sharda et al. (2014) and Valacich and Schneider (2018) raise BI and advanced analytics influence over an organization´s improved decision-making. Additionally, Brynjolfsson et al. (2011), as well as Berndtsson et al. (2018), mean that companies using data-driven decision-making tools have a higher performance level than those who do not, in terms of, for instance, market value and productivity. However, BI tools give users the opportunity to plan their future processes, by analyzing mainly structured or semi-structured data they help the users to understand both historical and current performance. Meanwhile, advanced analytics mainly guides users to build predictive models for both human and automated decisions, by helping them to understand why certain events happen, using structured and unstructured data (Valacich & Schneider, 2018).

Berndtsson et al. (2018) put a lot of emphasis on businesses that should provide their staff with easy-to-use tools so they may conduct independent research. This necessitates training users on how to utilize the tools and could increase demand for the availability of relevant data. However, a company that provides its employees with simple access to data enables ideas to be tested more rapidly and leads to the creation of new insights. The design itself for the tools being used should be linked with the overall project during the product development phase, according to Zuin et al. (2020).

Berndtsson et al. (2018) also stress that senior management must always take into account the fresh perspectives generated within the organization. Employees will not feel comfortable developing and testing novel concepts and findings, and the organization will not develop a culture that is data-driven in such a situation if the management is not in line with fresh perspectives. Zuin et al. (2020) agree with these statements since it is important to highlight all potential issues that can necessitate adjustments, incur additional expenditures, and cause implementation delays.

2.2 Humans working and collaborating with machines

Tan (2022) explains that studies repeatedly reveal that human error is the main factor in logistical mishaps. Although most human drivers are safe, a sizable and unpredictable fraction of individuals is to blame for the majority of incidents. At the same time, Wang et al. (2019) discuss the concept of Human-robot collaboration (HRC), which simply is humans and robots working closely together in a manufacturing environment. The concept refers to an environment where humans and robots interact with each other, and share the same workspace. It can be described as a mid-way solution between human labor and fully automated production. HRC combines the benefits of both sides, where humans still have expertise in the form of versatile problem solving, intuition and flexibility, while robots have expertise, as for instance, high accuracy and strength.

Wang et al. (2019) state that the research for HRC has been extensive for the last decade. Meanwhile, human responsibilities, in a working environment in close proximity to robots are still inexplicit. What Wang et al. (2019) mean is that the relationship should not necessarily be described as collaborative and that it could be a question of whether the relationship between them are coexisting, interactive, cooperative, or collaborative.Where coexistence, which is the basic situation, implies humans and robots that share the same space

but do not overlap on each other's workspace. Interaction is a situation where humans and robots share a workspace and also communicate to each other, which often means that one controls the other to achieve a task, or that some sort of physical contact between them occurs (Wang et al., 2019).

Matheson et al. (2019) state that cooperation is simply when robots and humans have separate tasks, but can share the same workspace, and thus also have the opportunity to gain from each other. Lastly, collaboration refers to when one is totally dependent on the other, and vice versa, in a shared workspace (Wang et al., 2019). This means that the two parts share a joint goal, and the tasks they perform are vital for the goal, and to provide the best conditions for the other part (Matheson et al., 2019; Wang et al., 2019).

Tan (2022) discusses how logistical accidents will not stop happening as long as people manage, direct, and control traffic vehicles. Developing economies found that if logistics accidents are avoided, it will improve economic gains in those countries by between 7.1% and 22%, according to World Bank statistics. The competitive nature of commercial logistics, including time constraints, schedule adherence, and travel stress, significantly raises the risk of accidents for logistic operators. Janssen et al. (2019) emphasize that the common interpretation of the introduction of automation may be that automated systems take over the execution of tasks from people, thereby reducing the number of faults, efforts, or attention that humans must devote to that activity.

Continuously, Tan (2022) means that concerning vulnerability, there are still a number of issues that need to be addressed. This includes privacy, hacking, abuse, prices, and a preference for traditional handling. The human aspect could potentially be a problem as long as human-operated and autonomous vehicles share the same infrastructure (Tan, 2022).

2.3 The importance of how inventories are managed

Moshood et al. (2021) write about the importance of quickly describing the primary function of logistics, which is to move everything from point X to point Y in an efficient manner. Maximum supply chain control provides access to a range of data that may serve as a basis for business decisions. One way of making an entire supply chain more efficient, according to Eroglu and Hofer (2011), is to embrace a lean way of working. Eroglu & Hofer (2011) mean

that those in favor of lean production see the term “Lean Inventory” as a waste that should be reduced. Lean management for inventory has come to be equated with effective inventory management in recent years as lean production has gained broad acceptance.

Further, Nasim et al. (2016) discuss the time frame and mention that lean inventory management differs greatly from traditional methods because it starts with the idea that inventory is a liability and not an asset. As a result, Nasim et al. (2016) mentioned there are typically no particular initiatives or programs designed to cut down on excess inventory. Inventory reduction is therefore a routine task at work. Anđelković et al. (2016) explain that the interpretation of lean production also now places more emphasis on continuously raising customer expectations for value and is not only cutting waste and costs. In a broader sense, it places emphasis on raising performance levels and reducing or eliminating some activities, depending on whether they add value or not (Anđelković et al., 2016).

Eroglu and Hofer (2011) ensure that total quality control, total productive maintenance, and just-in-time are a few examples of lean practices that are typically included in the concept of lean production. Additionally, numerous studies reveal that the adoption of lean production practices has a positive impact on financial performance (Eroglu & Hofer, 2011). Further, Nasim et al. (2016) highlight the importance that the lean initiative has to be backed by the entire cooperation in order for it to be truly successful. Anđelković et al. (2016) in turn mention the statistical side and explain that warehousing costs make up two to five percent of a company's overall expenses. The distribution of these warehousing costs are; labor costs (60%), space costs (25%), and equipment costs (15%).

Nasim et al. (2016) acknowledge that an inventory warehouse is just another "supermarket" where products are kept for sale, and you only have a supermarket if you cannot meet customer demands for your products at the time and place they want them. Anđelković et al. (2016) reveal that lean manufacturing reduces human labor in the factory by half, as well as it reduces the amount of space used for manufacturing, the cost of tools, the amount of time it takes to produce a new product, and the amount of inventory needed. All of which reduce mistakes and waste. Eroglu and Hofer (2011) agree with this statement and explain that the outcomes of lean inventory management means that the labor requirements drop, inventory turnover increases, and earnings per share rise after the implementation of lean production.

At the same time, unit manufacturing costs rise and operating margins decline (Eroglu & Hofer, 2011).

Furthermore, Anđelković et al. (2016) point out that lean warehousing is a philosophy that calls for continuous, methodical, quantitative and sustainable improvement of the warehousing process with the full involvement of all employees. On the other hand, Eroglu and Hofer (2011) imply that lean production might not be appropriate for a specific company using certain technologies or operating in a specific sector. Therefore, an organization's different products, production technology, or demand characteristics, might lead to certain businesses not being amenable to lean inventory strategies.

There are according to Anđelković et al. (2016) wastes that are commissioned during a warehouse that hinder the lean philosophy from truly blossoming. These wastes are:

- **Defects:** Consists of tasks brought on by rework, returns, or adjustments made in response to customer requests due to errors made during the handling and transportation of items leading to them being damaged, defective, incorrect, or mislabeled.
- **Mistakes:** Inventory inconsistencies, or missing components also have a role to play in this.
- **Overproduction:** restocking, packing, and selecting goods before they are required.
- **Waiting:** involves picking, shipping, waiting for data, inspection and control waiting.
- **Unnecessary movement:** Focuses on unnecessary movement of employees caused by an inefficient way of routing.
- **Unnecessary inventory:** any circumstance that results in an excess of inventory, the freezing of company assets, a stock out, or the improper use of space.
- **Transporting:** Includes unnecessary internal inventory transportation (materials or products)
- **Inappropriate processing:** Include picking and packing orders, as well as irrelevant inspection tasks.

Furthermore, Nasim et al. (2016) discuss the term “Slotting”. The term is used to describe how space is used, but it refers to more than just where things are kept in a warehouse. It also attempts to establish a few standard location sizes and considers how much inventory can be stored in the location. The simplified explanation is that slotting is about having designated

spaces for certain components whilst considering that the total amount of pallets and components are not exceeding the optimal limits. It is therefore about having a clear structure regarding the inventory management (Nasim et al., 2016).

Kumar (2016) explains that a company must keep inventory at the appropriate level because such an investment entails a financial commitment. The company loses the chance to use those funds more wisely whenever they grow too big. Similar to that, the company could lose sales if the inventory levels are too miniscule. There is a level of inventories that is ideal, which can differ between companies (Kumar, 2016). How much holding inventory costs is discussed by Gurtu (2021) who means that holding costs usually is based on a fixed rate that is considered the same for all inventories within an organization. On the other hand, Ghasemkhani et al. (2019) mean that calculations of inventory costs often vary among organizations. Gurtu (2021) does however argue that the inventory holding costs should not be a fixed rate if the products are heterogeneous, since it costs more to for instance store refrigerated products than non-perishable products.

Furthermore, to understand whether something in stock is worth keeping or not, Gurtu (2021) means that there are many variables to consider. For instance, the costs of holding something are not explicitly allocated for the costs of storing it at a fixed spot, the product must also at some point be handled, manually or by machines. This means that there are also additional costs for the handling time which should be included when calculating such costs (Gurtu, 2021). Aro-Gordon and Gupte (2016) add that there should also be a use of applications that give organizations a structured method of accounting for all incoming and outgoing flow of inventory within their facilities. In addition to that, reacting fast to changes within the organization is of importance since time is always essential when it comes to inventory management and cost optimization (Aro-Gordon & Gupte, 2016).

2.4 Theoretical framework

The literature review resulted in a theoretical framework as follows. Figure 2.1 shows how the different articles cover different topics that are relevant to the research questions. The third heading “The importance of how inventories are managed”, is the framework for how inventories should be managed and is thus the framework for this situation. It is, however, not explicitly applicable for automated environments. Therefore, the first two headings are

included to put the third one in the right context. Consequently, the third heading is the starting point for how the components should be managed, while the first heading can put that management in the right context, and the second heading is the framework for the engagement between heading 2.1 and heading 2.3. The framework will later be used together with the results to analyze the situation in the studied area.

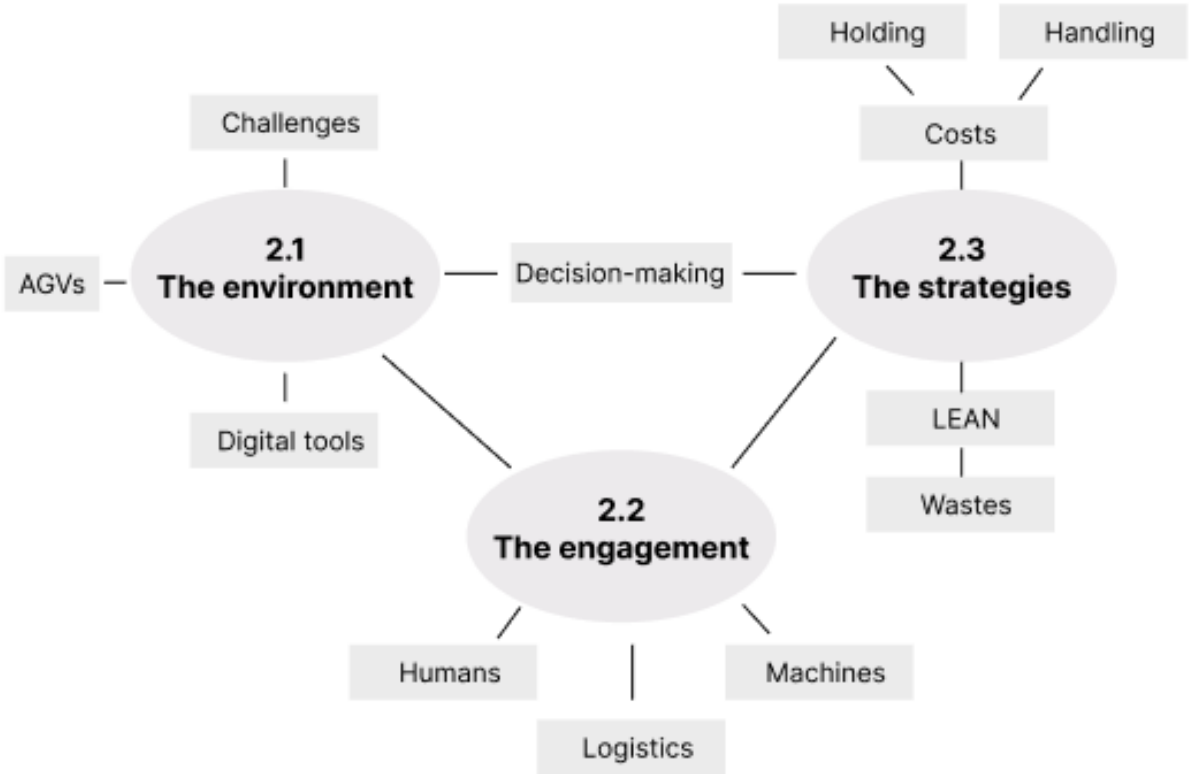

Figure 2.1: ***Theoretical Framework.***

3. Case Description

In this chapter, information about the case company will be brought forward as well as data and knowledge about the studied area. Lastly, the different materials flows for in the factory are presented in a figure to show which part of the flow this study focuses on.

3.1 The company: SKF

SKF is a global leader in the production of bearings, seals, lubrication systems, and condition monitoring systems. Since its founding in 1907, the company has experienced continuous growth, and it today serves clients in more than 130 nations worldwide. SKF has a long and distinguished history of developing products. The business debuted the first self-aligning ball bearing in the world in 1948, and over the years, it has proceeded to develop numerous new goods and services that have significantly impacted its sector. The business also consistently makes research and development investments (SKF, 2020).

Because of its dedication to innovation and teamwork, SKF has been able to stay at the forefront of manufacturing and maintain its position as a key global leader in its industry. Overall, SKF is a significant global force in the manufacturing sector, providing products and services that are intended to satisfy the demands of clients all over the world. SKF is positioned to maintain its momentum and continue to be a leader in its sector for years to come because of a strong history of innovation and a dedication to quality and sustainability (SKF, 2020). Additionally, SKF has its headquarters in Gothenburg, Sweden, and was in 2017 ranked as the 38th Top Multinational Performer in the world (Forbes Magazine, n.d).

In 2015, SKF made a decision to invest 190 million SEK directly to the modernization of their production of spherical roller bearings. By the year of 2017, the new fully automated and digital production process was inaugurated, which meant less cost per unit, better quality, and better working environment for the employees (Svensk Verkstad, 2017). This refers to the D-factory in Gothenburg, which thus is a factory oriented and active in the Industry 4.0 environment.

3.2 Studied area: “The basement”

The research object referred to as “The basement” is a part of SKF`s automated production in their D-factory, and the simple explanation for its name is the fact that the basement is the floor below the actual automatic production. It is the last place final products cross in the factory before being shipped. It is thus, the end station of the materials flow in this factory. In the basement, finished boxes of products on pallets or half pallets arrive, to then be automatically taped. The tape machine must, however, manually be managed, primarily in terms of changing the tape roll when the previous one is empty. When the boxes are taped, they roll on a conveyor which at the end has sensors. These sensors in turn send signals to the AGV that packages are ready to be moved. Then an AGV picks up the pallet or two half pallets with its forks and transports it to the end station, where later internal truck drivers pick them up using manual electric forklifts.

AGVs can appear in many different forms (Chakma et al., 2019). In the factory the AGVs operate as forklift drivers and have two forks that can move and carry pallets. The traveling part is based on a digital trace that has been programmed into the floors, which means that the routes traveled are always the same and therefore predictable. When there is a turn, an indicator is used and a horn is activated.

In addition, the basement involves the management of returns and abundance in production. A reason for the abundance is intended overproduction, where a decided percentage margin beyond what is required is produced, this will be referred to as “Scrap margin”. The reason for this is to ensure that the production rate will be sufficient. Thereby, if everything works exactly as it is supposed to, some components become redundant. Another reason for redundant components are also obstacles in production, which means that a planned production is being canceled midway. Therefore, some components become redundant and need to be stored. Consequently, the basement acts as a warehouse to some extent, where components of the final products are stored.

So, the basement acts as both the final station for finished products and as a warehouse for the redundant components. The AGVs´ range of movement is however relatively restricted in this area. Simply explained, the AGVs` only responsibility is to manage pallets containing finished bearings, while the redundant components are outside their working area.

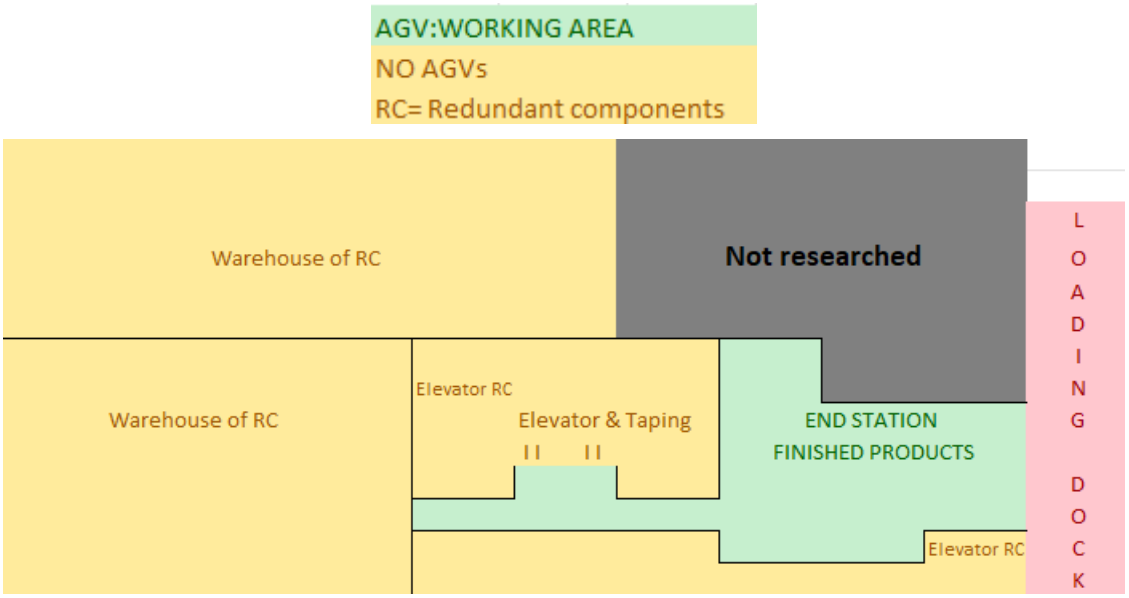

Figure 3.1: ***Simplified map of "The Basement".***

3.3 Redundant components flow

The entire factory, consisting of mainly two floors, has overall an automated materials flow. Except for unloading from trucks, stacking into racks at the beginning, and loading on trucks at the end, the flow is fully automated. However, the redundant components flow is in principle the opposite. The only part that is handled by AGVs is when components are moved from a production channel to a "return area". All other parts of this flow are handled manually.

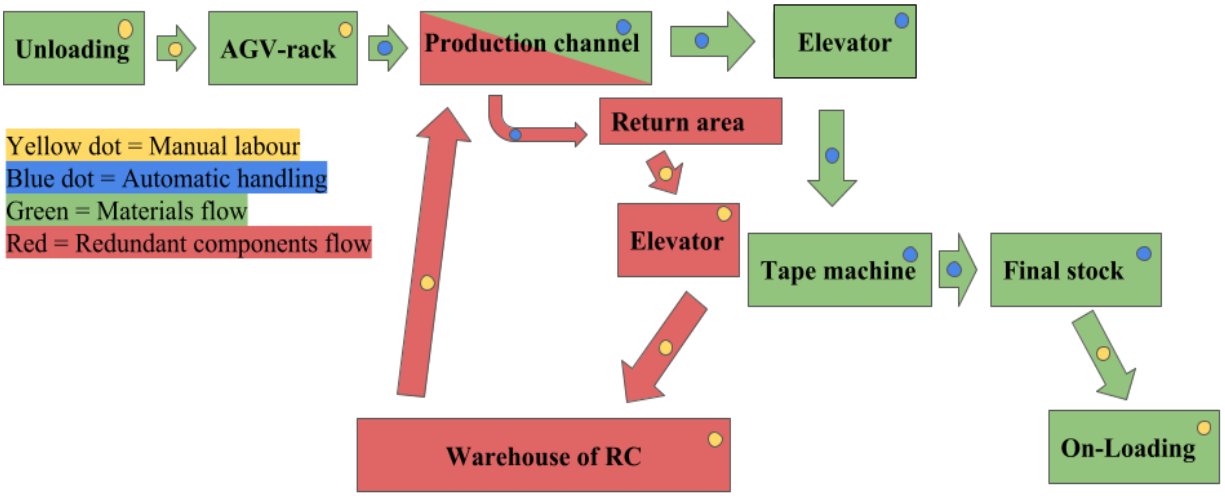

Figure 3.2: ***The materials flow.***

Note: The red headings are the primarily investigated areas in this study.

4. Methodology

The following chapter explains and argues for the chosen methodologies and strategies in the thesis. The chapter starts with a discussion about research paradigms, which later leads to the chosen data collection methods for the identified paradigm. Later, the data analysis is explained as well as the research´s quality, ethical measures and limitations.

4.1 Research Strategy

According to Collis and Hussey (2014), the determination of which research paradigm to position in, is one of the first steps to take when designing a research paper. Paradigms can be described as philosophies and world perspective, i.e., how the researchers view the world and their assumptions about it, and this philosophy will be essential for the study's methodology (Collis & Hussey, 2014).

In this case, as well as others, depending on which paradigm the researchers decide to categorize themselves as, the method itself would be affected. The positivist paradigm has historically been dominating logistics research, and this refers to a world that can be seen as objective. Thus, quantitative methods are dominating due to their characteristics of high levels of collected data that could be reflective of an objective world (Näslund, 2002). The contrary worldview to positivism is interpretivism which entails that the social reality cannot be explained as objective. Interpretivism explains social reality as subjective, this is because everything is shaped by the viewers, researcher, or any person's perception of the given situation (Collis & Hussey, 2014).

Due to the aim of this study, where evaluation of materials flows in an automated environment including AGVs, robots, and human workers, the investigation could be put in context of both the positivist and interpretivist paradigm. With a positivist point of view and thus using quantitative methods, the research could be conducted by collecting large quantities of technical data for analysis from for instance the AGVs. An interpretivist could examine the same issues by for instance interviewing people about the matter, to then understand the employees' view of it. However, Collis and Hussey (2014) do not challenge the choice of using mixed methods that could be placed in both ends of the paradigm spectrum. In fact, Näslund (2002) encourages taking a multi-paradigmatic approach to develop future research. However, this could be performed using only qualitative methods,

since Näslund (2002) means that qualitative research should be perceived as multi-paradigmatic and not interpretive.

The researchers of this study would according to Collis and Hussey (2014) be described as interpretivists. If also taking Näslund (2002) into account, the more accurate term would be multi-paradigmatic. Thus, the study primarily gathers data using qualitative methods, but elements of quantitative nature will also be included, using mixed methods. That process will be further elaborated later in this chapter. Additionally, Bryman and Bell (2015) state that a mixed method approach must be well motivated for the sake of the research paper´s quality. Motivations for the used methods in this paper will hence be discussed throughout this chapter.

Another question to raise of high importance when conducting research is the chosen research approach. The three main approaches are: deductive, abductive and inductive (Patel & Davidsson, 2019). If these three approaches were to be placed at a spectrum, deductive and inductive approaches would be placed in each end, and the abductive approach would have the position in between the other two. To clarify, a deductive approach is fundamentally a method that uses previous literature and earlier studies to test hypotheses on the research object. Meanwhile, an inductive approach, at the other end of the spectrum, is built on tests or observations that later could end up in theory, depending on which direction the observations lead to.

This study could be described as abductive, which simply can be explained as a combination of the deductive and inductive approach. Generally speaking, the abductive way of working is the use of an inductive approach, in terms of understanding an individual case with the purpose of developing theory based on this declaration. At the same time, abduction means that the theoretical background should be placed in a new context after something is observed. Hence, the abductive approach can develop the very foundation of the theory (Patel & Davidsson, 2019). For this study, this means that the research itself is not entirely based on theoretical background, since some findings demand extended theoretical perspectives to push the study forward. It also means that the study is based on assumptions that there are issues with SKF´s materials flows. Lastly, the study uses earlier research to create perception of the given situation, in a general context, mainly with the purpose of creating the best possible strategy to conduct the research.

4.2 Research Design

This study has been conducted through a case study approach, which according to Yin (2018) is a favorable approach when seeking answers of problems that can be characterized with words as “how” and “why”. The second research question of this study is “How can the identified problems be opposed?”, and thus suits the case study approach and is coherent with its characteristics. The first research question “What are the problems for the management of redundant components in the studied area?”, also has the aim of understanding how these problems are connected and why they occur. Thereby, the first research question suits the case study approach as well.

Additionally, this study that investigates issues related to industry 4.0 for a specific case (SKF), would be considered generalizable for a real-world context since the problems themselves are not necessarily specific for the investigated company. The issues could occur for any producing company or organization present in the industry 4.0 environment. Thus, a case study approach and to investigate a specific case is relevant, since the research is embedded in a real-world context.

Continuously, Collis and Hussey (2014) argue that case studies have the purpose of exploring a single phenomenon, but to procure in-depth knowledge by using multiple methods. The methods can be of both qualitative and quantitative nature, despite the fact that case studies often are associated with the interpretive paradigm. This case study could be described as opportunist, which means that access to a particular part of an organization, SKF in this case, has made it possible to conduct the research (Collis & Hussey, 2014). Additionally, Collis and Hussey (2014) mean that an opportunist approach can generate very original solutions, even though it can be moderately constrained. It would however not be incorrect to describe this case study as experimental, i.e., “...where the research examines the difficulties in implementing new procedures and techniques in an organization and evaluating the benefits” (Collis & Hussey, 2014, p. 68), since it has the aim to develop and test new solutions for a problematic environment, based on existing research within the field.

Furthermore, “Action research” is also a methodology mentioned by Collis and Hussey (2014) that should be discussed in the context of this investigation. Action research involves two goals, to contribute to science and solve a problem for a client, which both are within the aim of this study. The simple definition of action research is “... a methodology used in

applied research to find an effective way of bringing about a conscious change in a partly controlled environment" (Collis & Hussey, 2014, p. 67). This could almost be the definition of this study, but critique in the form of comparing this methodology with journalism and consultancy instead of perceiving it as scientific research is taken into consideration. It should however be emphasized that even though this study could be described as action research, the aim of generalization is crucial. The study does not exclusively aim to solve problems for the studied company, and thus contributes to scientific research, it also has the aim of contributing with solutions that could be applicable in other fields.

4.3 Data Collection

For this case study, several methods have been used, which is crucial when investigating a single case (Collis & Hussey, 2014). The primary data collection consists of various methods and the secondary data is mainly collected by conducting a literature review.

4.3.1 Primary Data

The primary data of this study has mainly been collected using a qualitative method, by conducting interviews. Data has also been collected by observing the basement and attending cross-sectional meetings. In addition to that, a small collection of statistics have been conducted.

4.3.1.1 Interviews

The first step of collecting primary data was to conduct interviews. The aims of the interviews were both to get background information about the basement, but also to understand different perspectives of how the materials are and should be handled in the area. Therefore it was crucial to interview employees with different roles in the company, with different areas of responsibility. Using interviews as a method is suitable for understanding what people think, do or feel (Collis & Hussey, 2014).

The interviews were conducted similarly for the interviewees. Some divergences do however occur, in the form of different questions for the respondents, mainly due to their different expertise and operational tasks. All the interviewees are anonymous and are each given an ID#, that number and their section and role are displayed in Table 4.1. As exhibited, the interviews were conducted with employees from three different sections, with three

respondents from the section “Factory logistics”, where those three respondents have different authority and tasks. The other two represented sections are “Automation” and “Supply Chain”, with the purpose of understanding those sections' power, interest and perceptions of the basement. Since the respondents have different roles and expertise at the company, and since this mainly is a qualitative research paper, the results will include any aspect from their response. This means that one respondent´s perspective can be just as important as two of the other respondents´ perspective, depending on the question. This also means that one opinion can be more valuable than several other opinions, if the respondent with that opinion could be considered an expert on the topic.

Interviewee	Section, Position	Date	Duration
ID1	Factory logistics, Forklift driver	22/02/2023	35 minutes
ID2	Factory logistics, Forklift driver and employee coordinator	22/02/2023	50 minutes
ID3	Factory logistics, Manager	23/02/2023	32 minutes
ID4	Supply Chain, Manager	07/03/2023	20 minutes
ID5	Automation, Manufacturing Reliability Engineer and AGV responsible	02/03/2023	25 minutes

Table 4.1: ***Interviewee Information.***

The interviews were conducted using a semi-structured approach where prepared questions were used as a base, but new questions that became of interest during the interviews occurred as well (Collis & Hussey, 2014). The interviews have, as mentioned, the purpose of understanding different perspectives of the issues in the basement, but also to understand the respondent´s view of what measures should be taken to mitigate those issues, depending on their role. Thus, the semi-structured approach was most suitable, due to its flexibility, which was necessary for the utilization of the responses. The prepared questions are of different character, including some closed, but the majority are open. The closed questions purpose is to understand if the interviewee has insight in the theme, and the open the get more in depth answers (Collis & Hussey, 2014). The unprepared questions do, however, also include probes and hypothetical questions.

The majority of the interviews were conducted face-to-face at the workplace, but one has been carried out over telephone due to convenience for the interviewee. Furthermore, each interview has been conducted one-to-one, but has been sound recorded, to facilitate the transcription process and to give insight to the non-participating researcher.

4.3.1.2 Meetings, observations, and statistics

In addition to the interviews, which primarily was the method for understanding the current problem situation from different perspectives, data was also collected via other methods. These methods did not only make the results from the interviews more valid and reliable, but also expanded and pushed the research forward. In other words, these methods ensured that the identified issues could be measured and put in a clearer context.

However, these data collection methods were possible to conduct since this study is action research at SKF in Gothenburg. Thus, some of the methods are not directly connected to any literature, but are yet conducted due to the opportunities the action research approach entails. One opportunity was to attend and participate in cross-sectional meetings about the basement. The purpose of the meetings was to make the area less problematic for the daily operations and to understand how this could be done, and take actions based on the common understanding. The meetings, which were initiated from the company, started during the research period and are planned to proceed after the period. More details about themes and participants can be found in Appendix 6.

Another opportunity was to observe the facilities. This made it possible to understand and see how the materials flows, as well as the employees and the area in general functioned. According to Collis and Hussey (2014), observation as a method is defined as "... a method for collecting data used in a laboratory or natural setting to observe and record people's actions and behavior." (Collis & Hussey, 2014, p. 148). The observations in this study do not focus on people per se, but focus on understanding the area, and the interaction between people and machines. The observations took place throughout the research period and were helpful for understanding for instance, employees and how they managed their own tasks as well as helping machines that required human assistance.

Lastly, some statistics were gathered to expand the data collection, but also to measure some of the findings from other methods, and thus make the study more reliable. Access was given to certain parts of SKF´s ERP systems to make this kind of data collection possible, and the data was collected in collaboration with employees at the company. The purpose of this method was to test some identified issues and to get an understanding of how the problematic areas in fact look like, statistically speaking. The collected data were both data that made it possible to calculate the costs of pallets with different parameters included, and data that made it possible to simulate potential time and cost savings. The actual underlying data is, however, not presented in study due to confidentiality agreements, but results of the simulations are displayed as well as descriptions of the variables. Since the variables are measured in different units, the relationships between variables that have the same unit are presented as a part of the results, instead of using a uniform index since that could make the data deceptive. The relationships are based on data collected from the period 1 January 2023 - 1 March 2023.

To sum up these three additional data collection methods, they all could be related to each other. The meetings made both the employees and the researchers understand what figures and statistics needed to be collected to measure the area´s costs. The collected statistics could in turn make the discussions and questions raised on the meetings more precise. Meanwhile, some observations were fundamental for understanding what the area looks like, and consequently also to understand how employees need to adjust to operate the best way possible in the area. Some observations also took place during meetings, where issues from one perspective could be discussed with people from other roles.

4.3.2 Secondary Data

The secondary data of this report is exhibited mainly in the literature review and the case description. Where the latter is a mix of both secondary and primary data. For the literature review, peer reviewed scientific articles stand for the majority of the sources, with some complements in form of books and journals. The literature review, which contains three main chapters, was a crucial part of the study due to its ability to create greater understanding of the research area, and potential problems and solutions within the context. At an early stage, it was nevertheless, not undoubtedly that the collected data for the literature review covered the areas which the study would investigate, and that evoked the decision of taking an

abductive approach. The two major tools for finding scientific articles, journals and books were Google Scholar and Gothenburg University Library´s search engine.

The case description does, as mentioned, also contain secondary data. Mainly, in the form of websites and official documents from SKF, but there is also information retrieved from web pages and online magazines. Since the basement is a part of the D-factory, no explicit information was found about it when searching for secondary sources. Therefore, the entire description of the basement is based on interviews and observations, which should be categorized as primary data and not secondary.

4.4 Data Analysis

The data collected in this study does not exclusively deal with issues directly related to the characteristics of automation, industry 4.0 and AGVs. It is also a question of employees' perception of the situation in the examined area. Therefore, the data analysis is an attempt to include several different perspectives in the study.

To analyze the data, a form of data display has been used in the study. The issues identified in the results, could be categorized and hierarchically set up with the intention of opposing the issues in the area. Therefore, the analysis contains an events flow network, which according to Collis and Hussey (2014) is a model "...useful for displaying a complex sequence of events, in terms of both chronological order and relationships." (Collis & Hussey, 2014, p. 160). The events for this events flow network are all the issues presented in the following chapter. This means that an issue is, in this context, the same as an event, and thus that the analysis will be based on a network of the identified events (issues) concerning the redundant components.

Furthermore, the events flow network is in this case a tool for categorizing the issues, to then connect them with other issues, and thus making it possible to derive one or more issues to another. Henceforth, the solution for one issue could be to attack another, if there is a connection between them. The arrows in the network are therefore directed towards the issue that one issue could be derived to and not the other way around, which could be described as a reverse events flow, since it is the opposite order to the events flow Collis and Hussey (2014) describe. The difference is described in Figure 4.1 below. Some events also have a

two-way relationship where both can be derived to each other, for those issues there are arrows in both directions.

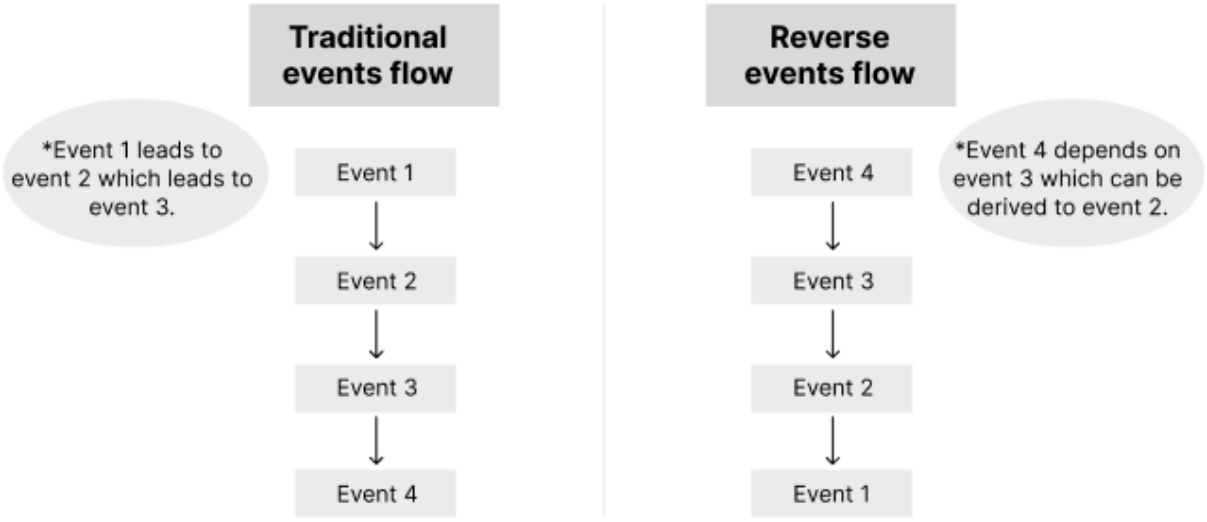

Figure 4.1: ***Different techniques for presenting events flow.***

Based on the literature review the results later also could be analyzed by placing the detected obstacles in a theoretical context, but as mentioned, it would also be the other way around in some cases, where the identified issues generate opportunities to expand the existing theoretical background.

However, there are also identified issues that are categorized as independent. This means that there is no derivation between the issue and the other ones, which accordingly imply that a solution can only be achieved if the issue is faced single-handedly. In addition, when trying to derive the identified issues, some of them could be placed in more than one sequence of events, which thus means it could be derived to more than one other issue. The events flow network is first displayed in its entirety including all identified issues. Afterwards, some of the suggested solutions, as well as, and in accordance with previous literature, are displayed in parts of the network where they could fit. Accordingly, the analysis exhibits the issue that should be approached to improve the current structure. Thus, the events flow network is the very foundation of the analysis while the theoretical framework is the guide throughout the analysis, to stay in the right context.

Lastly, the data analysis that led to several different types of solutions, required new measurements. Thenceforth, those measurements are presented in the analysis and then analyzed as well.

4.5 Research Quality

When determining the quality of research, two common measurements are validity and reliability. Both terms are related to the measurement of the chosen methodology, and will be further discussed in the subheadings below. An important term for case studies in general, and henceforth also this one, is “triangulation”. The term refers to the use of different methods applied to the same situation, or that multiple researchers examine the same phenomenon (Collis & Hussey, 2014). For this case, triangulation is achieved by using several methods applied to the same situation, using interviews, observations, meetings and gathering statistical data from SKF. Using more than one method, and to be included under the concept of triangulation, make it easier for a study to achieve great validity and reliability, in comparison to using a single method (Collis & Hussey, 2014).

4.5.1 Validity

Validity can be described as how well a test measures what is intended and nothing else, which simply means that the concept refers to the evaluation of the data collection method. If a method has good validity, it should be a method that can give the study the right results and not measure something outside the aim (Collis & Hussey, 2014). For this study, the validity could both be emphasized as good and doubtful. The reasons for this are self-evidently depending on the choice of methods. The predominance of using qualitative methods, could arguably be contradicted in a very technological environment. Thus, using quantitative methods, and collecting more numerical data could have steered the research in another direction. Contrariwise, it could be argued that the qualitative approach has investigated nothing other than what is in the scope of this study, and therefore it has, per definition, a good validity. To be more precise, the used methods measure what problems that do occur in the basement from different perspectives, at the same time as it is controlled through observations, meetings and statistical data.

4.5.2 Reliability

Accuracy is a keyword when describing reliability, which simply can be described as the measurements precision. Thus, a study´s reliability is high if it can be conducted repeatedly with the same results (Collis & Hussey, 2014). Furthermore, Collis and Hussey (2014) state that a positivist study is more likely to obtain high reliability than an interpretive. Meanwhile, an interpretive study focuses on how the “interpretations” could be understood, and thus it

would not be perceived as reliable in a positivist sense, but reliability could yet be achieved from the interpretive perspective. However, Collis and Hussey (2014) mean that interpretivist studies in general often have higher validity, while positivist studies have higher reliability. This idea could also be applied for this situation. The study, with predominant use of qualitative methods should, as mentioned, be considered a study with high validity. High reliability is then, according to Collis and Hussey (2014), more difficult to achieve. To counteract this, the choice of methods has contained decisions to make it as reliable as possible, by achieving triangulation, but also by using underlying statistical data to stabilize the research.

4.6 Ethics

Ethics in a research environment, according to Bryman (2018), refers to how people and organizations are treated when taking part in a research endeavor. This thesis has adhered to the four key ethical norms of voluntariness, confidentiality, anonymity, and integrity. Kennedy (2008) mentions that respondents may disclose information that cannot be associated with them by virtue of anonymity, which can serve to protect privacy. Anonymity may therefore encourage more collaboration when doing the survey involves significant risks for the participants.

Asking the respondents about their willingness to participate in an interview helped to ensure the first principle, the voluntary nature of the empirical collection. If they objected after agreeing to participate, it was made plain that there was no issue and that they may change their minds and return to the interviewers. The second requirement, confidentiality, was ensured by keeping all information private and only accessible to the authors during the time when recordings and messages were being saved. The third criteria, anonymity, was upheld by withholding the respondents' names from anybody other than the thesis writers and assigning them a code name such as "ID3" when they agreed to participate. The respondents were given the choice of interrupting the interview or taking a break if they felt uncomfortable answering a question. This ensured the fourth principle, integrity, at the outset of every interview.

4.7 Limitations and Bias

The research is conducted during one semester and is thereby, for the topic, relatively time constraint. More time would have changed the outline of the study in terms of how concrete the results of the study are. In other words, more time would have given the opportunity to also test some countermeasures for the identified issues, and follow the development of the area. Hence, a longer time period would have made it possible to present more accurate results to the given situation, which in turn would have given the research a higher reliability.

Furthermore, the primary data collection of the study is, as mentioned, mainly conducted through interviews with five respondents with different roles. The basement is a part of all their different roles, but in different ways and to various extents. It could however be argued that a qualitative data collection with only five respondents could be a victim of bias. The use of several methods and achieve triangulation have thereby been the counteraction to bias, in accordance with Collis and Hussey (2014, p. 71). All included primary methods have although been conducted alongside employees at the company, therefore there is a risk that the results have been affected by their opinions. The guidance from employees also means that the study has been limited to research issues that at least one employee is aware of, and that some substantial factor could have been excluded from the research. The quantitative data collection thereby has a crucial role to the results, even though the collection is within context, relatively small. The role is crucial since it, regardless of guidance from employees, gives exact results. Hence, the qualitative results and statistics can together be analyzed and lead to fair conclusions about the situation, and minimize the risk of bias.

5. Results

This chapter presents the results of the methods for collecting primary data. The first and most extensive part displays the results from the interviews, which is the foundation of the study. Later, results from observations, meetings and collected statistics from SKF are presented to support data from the interviews and to achieve triangulation.

5.1 Results from interviews

The interviews resulted in several different perspectives of the basement´s situation. Some respondents have more insight concerning specific areas, where others have no insight. Therefore, some of the following sub-headings exclude some of the respondents. The interviews´ results are displayed through five sub-headings, where the final one is a summary of the identified perspectives.

5.1.1 Identification of issues with the basement

ID1

One of the main issues is that items and pallets are placed in the wrong areas by personnel. With different projects that are ongoing in the basement, external personnel that are not a part of SKF, and hence do not have access to the ERP system, move things around but cannot register the movement in the system. The lack of space to store new redundant components in the basement is also an issue. This is because employees tend to find places in smaller areas and try to squeeze the pallets into areas that are already filled with other pallets. The consequence of this is that the space becomes even more filled and unstructured, which makes it hard to find pallets, which in turn takes unnecessary time.

Another issue is the lack of employees. Even if the strategic decisions to make the factory automated is reasonable to stay competitive, the employees' tasks have not decreased, but the amount of employees has. In turn this leads to human errors due to stress, the employees do not have time to do their work as well as they should. Henceforth, their operative decisions could be the best short-time solutions, but have devastating consequences on a long-term basis.

ID2

One problem is that there are a lot of small temporary solutions that have become permanent, some locations in the basement do not exist anymore. Numerous new locations in the basement that are connected to previous areas that have been moved to a completely different location. For instance area three reasonably should be next to area two, but instead it has been moved further away into another completely different area in the basement. This itself is from the beginning a temporary solution in order to utilize space in other parts of the basement, but the solution seems to be more temporary as more time passes. This makes it important for the workers to memorize where different locations are instead of using common sense to try and find them.

A second problem is the difficulty in finding different components and pallets. This also occurs in deep stacked areas where there are a lot of pallets close to each other. It could be very difficult to identify the desired pallet, and accordingly, it is very time consuming for the workers. Relating to time, when a worker finds the desired pallet, it often requires movement and rearrangement of other pallets to access it, and many times the worker, who already took a lot of time searching for the pallet, does not have the time to put everything else back as it was.

Additionally, the projects in the basement are handled like individuals and not like the “big machine” it should be handled as. Therefore, the projects collide with each other and the rest of the area, and become a bottleneck for the operations.

Moreover, the ERP system has some places in the basement that do not exist in reality. These areas were made to temporarily store components, but the issue now is that people tend to use these “imaginary surfaces” when a pallet in reality is placed somewhere else. This means that workers tend to put certain pallets and components in these made-up locations that only show in the systems and not in real life for simplicity purposes. This also leads to a lot of time spent in finding certain pallets since if they are in one of these made up places, they could actually be anywhere in the basement.

Lastly, the basement´s characteristics as a warehouse are not optimal, since it is not standardized for pallet racks. There are plenty of pillars that hold up the roof and therefore limits the space for any type of bigger objects to be implemented into the basement.

Accordingly, it is difficult to fit in pallets anywhere in the basement and the forklift drivers need to squeeze them in wherever there is space.

ID3

One of the main issues with the basement is the lack of structure. The bad structure can be derived to the space limitations and to the reconstructive work in the area. AGVs are a helping hand to some extent, but they can also be an obstacle for employees when things go wrong. This could be set in a context of poor system integration, where AGVs and forklift drivers use separate systems that are not fully compatible with each other. Hence, when something related to AGVs is a disruption it often can be derived from poor communication between the systems. Furthermore, the elevator for transporting redundant components often requires maintenance and thus is slowing down the working pace of the forklift drivers. Back to the structure, a few years ago the basement was divided into segments with pallet racks connected to their production channels, this made it easier to find pallets compared to today's deep stacking.

ID4

When pallets are assigned to a specific area in the basement, it often means that the pallet is there. If not, it is harder from a production planning point of view, to trust that the pallet actually exists. Additionally, the basement probably contains more pallets than the system exhibits, since some pallets have been written off just because they were not found.

ID5

The basement can broadly be divided into two areas, the area for handling finished bearings and the area for redundant components. Despite the fact that the first one has too many people, both external and internal, that are moving around things, it works well. The latter could, on the other hand, be a very difficult area sometimes. A big problem today is that the basement is full, there are too many pallets and too many objects that should be considered as waste in the area. Accordingly, there is an issue of finding pallets because of for instance the necessary action of deep stacking pallets, instead of placing them separately, which takes unnecessary time. The deep stacking also depends on the company's digital systems. The systems are sufficient to control the material but the actual pallet position is problematic. The systems allow a deep stacking position to contain an endless amount of pallets which eventually makes the space overfilled. Thus, the digital systems allow the employees to freely

decide where the pallets should be placed, which in turn leads to a high risk of human impact and errors in the area.

In addition to the systems´ allowance of misplacing pallets, the integration between the different systems is also inadequate. Which system a pallet is in depends on where it is in the facilities. For instance, if a component on a pallet is not used in a production channel, it shifts system and goes down to the basement, since AGVs will not handle it. Then the same component can go up to the production channel, go back to the first system again, and then not be used again, and thus go back to the other system once more. This means that components always get new dates and that "...theoretically, a ring could bounce up and down endlessly" (Appendix 5).

Furthermore, the basement is to some extent everybody's responsibility, but consequently also sometimes no one's responsibility. If for instance the factory logistics workers saw the basement as their operational area, many problems would disappear in terms of structure and all things that implies. From the more digital solutions perspective, much could be done in the ERP system, for instance limiting the surfaces would of course make a difference. Accordingly, everybody has their part in making the basement, and the management of redundant components more efficient.

5.1.2 Potential areas of improvement

ID1

One of the main things is to make sure that the ongoing projects in the basement need to be fulfilled at a higher tempo. For instance, external companies enter the basement with the purpose of building new pallet racks, when one is finished it can take several weeks until they return to build the next one. This itself makes the basement much more unstructured and a difficult environment to work in, since it limits the workspace even more than it already is. So, if these projects were conducted more efficiently, it would be easier to follow the structural changes in the area.

The strategic decisions SKF has to make, considering reducing the amount of employees to enhance automation, are understandable. In order to stay both competitive and to keep the factory in Sweden instead of somewhere else, it is vital to make cutbacks. The issue, in this

case, is that no objectives for the workers have been reduced or removed while the amount of personnel has decreased. The tasks are just as many as they were before, but distributed among fewer employees. As it looks today, it would be vital to have someone that is dedicated only for the work in the basement area. SKF has a vision of how the future will look but the actual route to get there is sometimes difficult for the employees to cope with and understand.

ID2

The reasonable way to structure the basement would be to replace all deep stacking surfaces with pallet racks, which ultimately would give each pallet a specific place. The structure of the way of working in the area is also insufficient, and needs to be amended. If you need to move an amount of pallets to reach the intended one, all the other pallets should be moved back to their positions, without any exceptions. To make this possible, the area needs to clear up space, otherwise a change in the way of working will not be possible. Something that would make the work easier at current state, would be to have different types of forklifts. For instance, forklifts with the forks on the side would complement the present ones with forks at the front, since more pallets would be easier to access.

However, the reason for why this unstructured area and way of working continues, is the digital systems. A removal of "imaginary areas" in the system would limit the forklift drivers´ impact on the structure, and hence pallets would be limited to specific surfaces. Instead the systems allow the employees to be "lazy" and place pallets on surfaces that have no space limit in the system, or maybe only exist in the system and not in reality, accordingly the pallet could be placed anywhere.

ID3

The first step to make the basement more utilized is to calculate how much space the materials in the area need to have an opportunity of being structured. Another point of view of the issue is to clear out all the pallets that are not still beneficial to keep, which will clear out much space and hence could utilize the entire surface. This requires some grounds or decision background to understand when a pallet costs more than it is worth. Furthermore, traditionally the basement stored pallets on racks based on their production channel, which thus made it easier to understand at least in which section of the area the pallets were located. This could possibly be a way to structure it in the future as well. In addition to lack of space,

the ongoing reconstruction work also makes the area more problematic than it could be since it both requires space and rearrangement of pallets.

ID5

Limiting the amount of objects in the basement would be very beneficial. The first step to do this would be to make sure that every pallet that is sent down really contains components that should be kept. So, a step to stop the inflow of redundant components that really are redundant, which costs more to hold than to scrap, would make a difference. This could also be applied on a short time basis for the pallets that currently are in the basement, to clear out the space. The overfilled surfaces and lack of space in the basement could be derived to the production channels on the floor above. If the channels do not send down components that probably never will be sold, much space could be cleared up.

Additionally, the digital solutions could be utilized better. Limiting the spaces to a higher extent would make it impossible to stack pallets on surfaces they should not be in. This would accordingly minimize the deep stacking surfaces and decrease the amount of unnecessary time it takes to search for pallets, but also decrease the time it takes to rearrange the deep stacking surface to retrieve the wanted pallet when it is found. Furthermore, if the deep stacking solutions could be replaced with pallet racks, the area would be easier to control, both in reality and in the systems. This could also in the future generate more efficient handling solutions, where AGVs could operate in the area instead of human drivers, which would minimize the risk of human errors.

5.1.3 The role of AGVs

ID1

The basement is an environment designed for human beings. AGVs are a great tool to make operations more efficient, but in this area, they often become more of a burden than a helping tool. On the upper floor there are a lot of AGVs, and it is not likely that the more they are, the better. They often get stuck behind one another and if one does not work it will affect the entire fleet. In the basement, there are four of them, which is still a major problem since they tend to have issues even though they are not as many as upstairs. Another important factor is that this factory was built in the 1950s, so the floors are not well built to handle these types of vehicles in the best possible manner. For AGVs to work there is a need for pallet racks, and there is no capacity for that. Humans do not have the lasers and the measurements to be as

exact as the machines. This means that AGVs will have difficulties picking up pallets from spaces where humans have placed pallets.

AGVs are rarely working the way they are supposed to for a longer period of time without having some sort of issue. It would be optimal to have someone being brought in on overtime and simply having one objective and that is to clear up in the basement, to go through all the components and see if the pallets can be used right away. It would give a desired structure to the basement. The network is not as accurate and precise in terms of connection in the basement. There have been times when certain components in different locations differ from the ones in the internal systems. Sometimes the programs that are suited for the AGVs are not communicating with the systems that forklift drivers are using, so the conclusion is that the AGVs themselves are not working in their best environment.

ID2

It would be more efficient to use AGVs instead of workers to handle redundant components. This could be made into reality if pallet racks, which are suited for AGVs, were implemented. With human workers they will always be at risk of errors occurring, this could be the pallets disappearing or being placed in areas that no one can find. This will probably not be as occurring with AGVs handling the inventory management. The AGVs make a significant difference, but not as significant as they could be. The AGVs make it possible to handle automated production channels in the basement where there is no personnel. There are however still many issues occurring with the vehicles that are very time-consuming, at the same time, it would be unfair to claim that AGVs are more problematic than helpful.

ID3

AGVs are not as implemented as they can be today. There are still issues occurring, but hopefully there will be major winnings of this implementation when the AGV flow is fully organized. AGVs are a helping hand, but it is obvious that when they start to have issues, it quickly becomes the employees´ issue as well. There are several occasions where the systems are not connected with the systems that the forklift drivers use. This itself makes the conditions much worse for the AGVs, and therefore makes systematic failure a reason for an AGV failure. It is therefore important to mention that it is not solely the AGV itself that is having disruptions, it is the systems surrounding it.

ID5

The AGVs in the basement have not yet made any significant difference in terms of efficiency. They handle the finished bearings, which takes away one task from the human forklift drivers, but that was probably one of the easier tasks they had before. The more difficult task the forklift drivers have is to handle the redundant components, which is outside the AGVs´ responsibility. If these components could be handled by AGVs in the future, it would make a significant difference. It would minimize human influence and in that way make the entire process more standardized. In a context where AGVs handle redundant components as well as finished bearings, major structural changes are required. Pallet racks, smaller pallets, better storage spaces, and easier handling of the pallets could make this possible.

5.1.4 Materials flow and data

ID1

Some components are more regular than others and therefore they are often being put back into the materials flow in a quicker manner than some other components that are more special and are only used maybe once or twice a year.

ID2

There is a limited amount of slots for certain components, for instance, grinded rings. It takes eight hours of staging for a 24 hour period, therefore that process becomes a bottleneck and demands more intense labor. An issue with this is that since time is of the essence, other production channels might prioritize the components on the upper floor since the slots are so limited and it is important to meet customers' demands. The downside is therefore that if it is difficult to find these components in the basement, by the time they have been found, it could already have been too late and the slots are occupied. This means that the pallet will be set up to the upper floor back into the materials flow, but will then be sent down directly again since it wasn’t found in time since there were no limited slots left.

Another issue is when there are shifts in production. Production channels can swiftly change the components that are necessary for certain bearings quickly. This will interrupt the entire process for the factory logistics process. This also means that it will be more difficult to use the redundant components in the basement and find them in a reasonable time when something is demanded right away.

ID3

The orders are staged from the planning section of SKF. The issue is the time span from receiving the order to actually picking up the pallet and sending it back into the materials flow because of the bad structure in the basement. This means that the lead time is the main issue. In a perfect world, having pallet racks in the entirety of the basement would be the best since it would be much easier for the forklift drivers to know where the pallet is to swiftly send it back into the materials flow.

ID5

There are several production channels and thus different materials flows. To describe one of them, it is fully automated except for two steps in the beginning and one step at the end. These steps are; unloading components that arrive, put these components in AGV-racks, and when the components have become finished bearings, they are manually loaded into trucks again. All the movement of components between mentioned steps are automated if everything works out as it should. However, if the procedure entails any redundant components, that flow is almost the opposite, and is more manual than automatic.

Furthermore, some programs can control and display the use of the AGVs in the basement. By using this program, it gives a view of problems and statistics that could be analyzed. The system can create charts that give views of upcoming errors. It is a well worked system to use in being able to log all the problems and then pass them on to the supplier of AGVs. The data shows one month's statistics and one week's playback. This can also be connected to a personalized app where the operators can log deviations with the AGVs. If workers notice an AGV standing and alarming somewhere, they can take a picture of it, write what number it has and the location of it. This information can be sent through the personalized app. There are meetings every week to go through all the inboxes. This logs the ongoing problems and can therefore later on be passed to the supplier of the AGVs in order to solve the issues.

5.1.5 Compilation of results from the interviews

Table 5.1 displays the respondents´ similarities and differences regarding general perception, problems, AGVs, and possible solutions. The table only consists of raw data and no elaborated categorization of the different identified perceptions since that will be the initial part of the analysis.

	ID1	ID2	ID3	ID4	ID5
General perception					
The basement is problematic	x	x	x		x
The basement works well				x	
Problems in the basement					
Too many temporary solutions		x			
Pallets are misplaced	x	x			
Pallets do not exist				x	
Difficult to find pallets-> takes time	x	x		x	x
Not enough space/too many objects	x	x	x		x
External people are an issue	x				x
Systems are not integrated with each other			x		x
No one is responsible					x
Doubtful internal communication between sections		x			
Projects do not work as they should	x	x	x		
Not enough human operators	x				
Human errors	x	x			x
Deep stacking		x	x		x
No decrease in tasks but decrease in workforce	x				
Production channels "return" too much					x
Reasons for redundant components					
Shifts in the production		x	x	x	

The scrap margin					x
AGVs					
AGVs could be the solution for redundant components		x	x		x
AGVs is not the solution for redundant components	x				
AGVs are not fully utilized	x	x			x
AGVs are helpful	x	x	x		x
AGVs takes unnecessary time	x			x	
Suggested solutions					
Dividing on production channels	x	x	x		
Replace deep stacking with pallet racks	x	x			x
Dividing on component type	x	x			
Utilize the space			x		x
Assign someone to structure the area	x				
Complete all started projects at a higher pace	x		x		
Using different kinds of forklifts		x			
Remove imaginary areas in the system		x			x
Compare holding cost vs pallet cost			x		x
Limit the amount of things			x		x

Table 5.1: ***Results from interviews.***

5.2 Results from meetings, observations and statistics

The meetings resulted in decisions about what should be done to utilize the space, which thus could lead to cost savings. Firstly, to create some sort of formula that could help making decisions about redundant components was discussed throughout the meetings. What should be included in such a formula were also discussed and led to collection of several potential variables that could be included, where some are presented as a number and some just as a variable. The variables collected from the systems are displayed in Table 5.2.

Variable	Unit	Sample selection
Average holding costs	SEK	Yearly average
Average labor costs	SEK	Yearly average
Average time for sending a pallet with redundant components to the basement	Time	1 January-1 March
Average time for retrieving a pallet with redundant components from the basement	Time	1 January-1 March
Pallet value (value of the components on a pallet)	SEK	Current-state
Amount of pallets in the basement	SEK	Current-state
Pallets going down to the basement	Amount	1 January-1 March
Pallets going up from the basement	Amount	1 January-1 March

Table 5.2: ***Collected variables.***

Due to the confidentiality mentioned, many variables could only be presented as what they are and not the actual values of them. Instead, below describes three different relationships between variables where that could be calculated.

1. First of all, for the sample selection, the time difference between retrieving and sending a pallet/half pallet was high. The collection showed that at the time one employee retrieves a pallet from the basement, seven pallets could be sent down to the

basement by another employee. Time means all the time an employee is engaged to a single pallet. Hence, search time or time for rearrangement is also included.

2. The data collection also showed that there were more pallets going down than up during the period. The relationship there was 100 to 121, which means that by the time 100 pallets have been retrieved from the basement, 121 pallets have been sent down.

3. The third relationship is between costs for holding a pallet and costs for handling a pallet. Figure 5.1 below demonstrates that an employee handling a half-pallet for one minute costs approximately 4.6 times more than it costs to store the half pallet in the basement for one day. The figure is based on an index on the left side where 1 equals holding costs for a half pallet/day. Since a pallet takes double the amount of space than a half pallet, that index value is 2. The labor costs for handling a pallet or half pallet do not differ and are therefore exhibited in one bar, with an index on approximately 4.6.

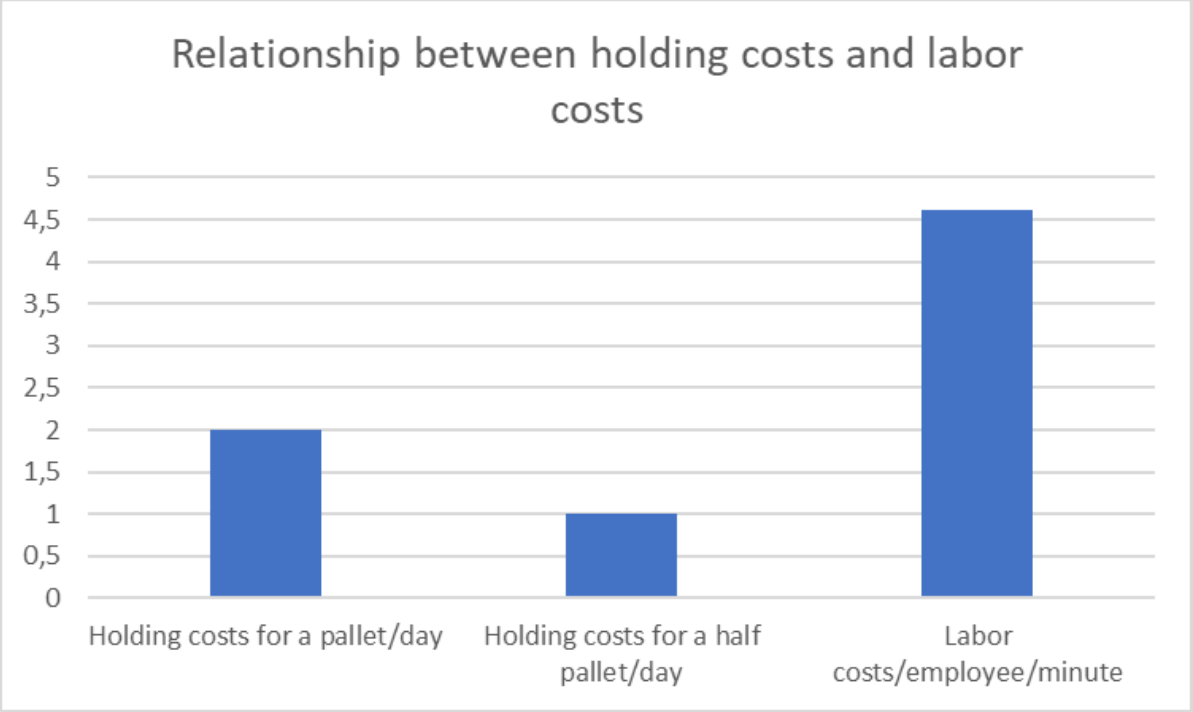

Figure 5.1: ***Relationship between holding costs and labor costs.***

Lastly, the observations and discussions during these observations, resulted in a common perception between different sections that the basement lacks an overall structure. The observations also demonstrated that some areas include storage of materials that in no way could be connected to SKF´s operations, in the form of old office supplies and inventories.

6. Analysis

This analysis is divided into three main headings, which all could be connected to each other. The first and fundamental one, "Application of an events flow network for the identified issues", is an attempt to connect all the identified issues in the basement. The second chapter could be described as a discussion of the events where most of the different levels and issues from the events flow network are contextualized. The final, and most extensive chapter, is an analysis of different solutions that could fit in the events flow network. To strengthen the analysis of the events, connections and possible solutions, the theoretical framework presented in Figure 2.4 is the guide.

6.1 Application of an events flow network for the identified issues

The results demonstrate that there are many issues in the basement, where some are more consistent among the respondents than others. As Figure 6.1 below exhibits, these issues can in one way or another be connected to each other, and they are thus presented in an events flow network (Collis & Hussey, 2014). Therefore, a suggestion for the first step for SKF would be to understand the connections and base their future decisions on them. Further, since the issues could hierarchically be divided, and categorized into groups, the network also consists of issues at different levels. The levels represent how likely they are to create new problems.

The events flow network could be perceived as going in the opposite direction than a traditional one. This is because the arrows point from an issue to the issue it can be derived to instead of the chronological order an events flow network usually entails (Collis & Hussey, 2014). The reason for this opposite approach is because the analysis starts from the lower grade issues to then go to the bottom with them. This means that the lower grade issues are initially examined to then understand why they occur. For instance, if looking at the issue "Deep stacking", it does not occur out of nowhere, some other unsolved issues have eventually led to that one. In this case, "Not enough space/too many objects" and "Systems aren't integrated" are identified as reasons for the emergence of this problem. The first could in turn be derived to both "No one is responsible" and "Production channels return too much", where the latter in the next turn leads to the issues "Shifts in production" and "Scrap

margin". In addition, the mentioned issue "Systems are not integrated" also leads to the issue "No one is responsible".

Furthermore, the flow of events described above contains issues that also are connected to other flows. In that sense, the events flow network demonstrates how the identified problems are, in one way or another, connected to each other. This analysis will, however, not focus on the events at level 5 in Figure 6.1 further, since they are fundamental issues and thus on a different decision-making level than the scope of this study implies.

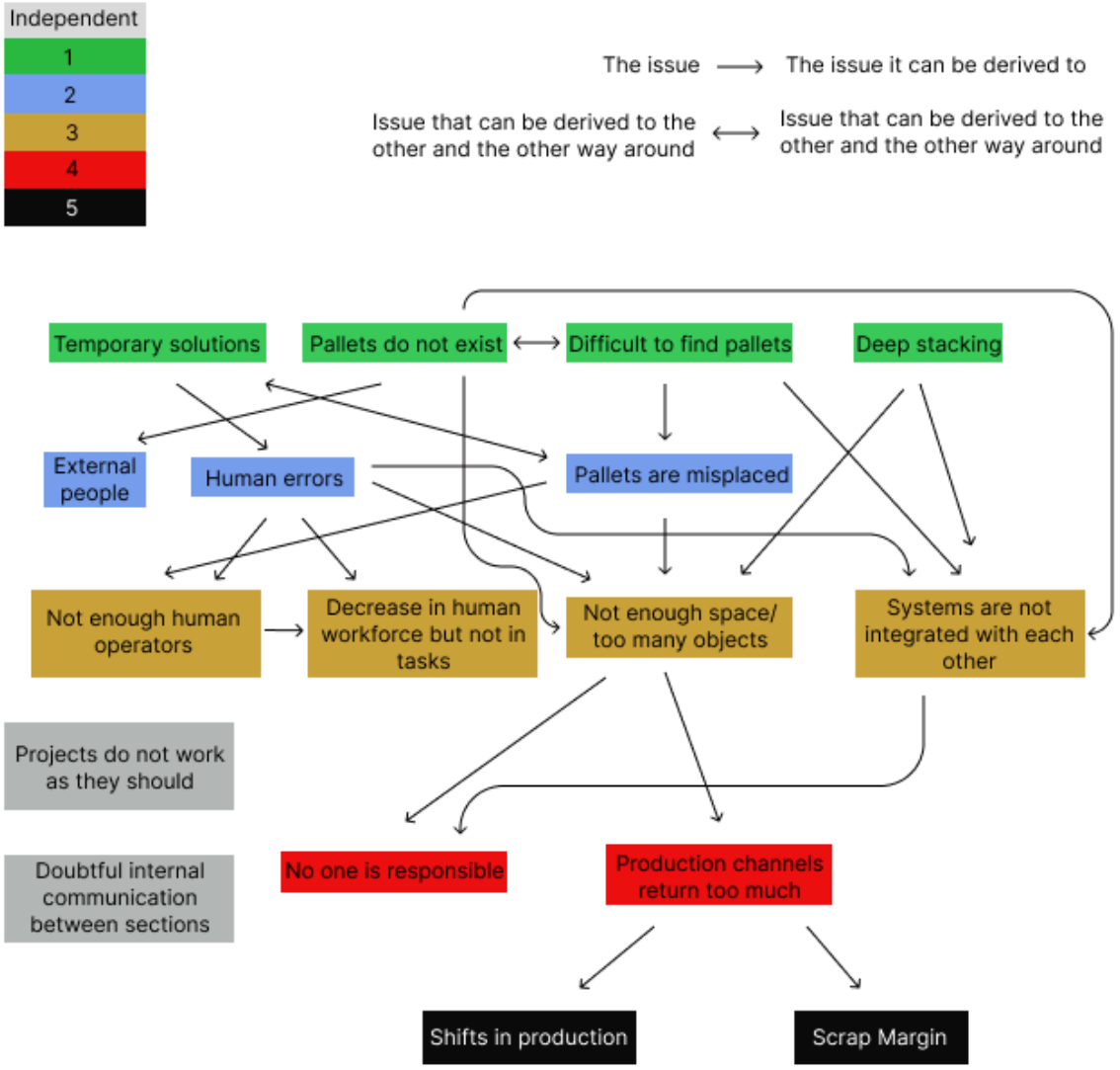

Figure 6.1: ***Events flow network for identified issues.***
The network displays and hierarchically categorizes all the issues identified from the interviews. The colors are based on a scale from 1-5 depending on an issue´s characteristics of creating more issues. 5, which is black, is the highest and thus includes the fundamental reasons for the rest of the issues, and 1, which is green, includes issues that do not explicitly lead to more issues.

6.2 Individual analysis of the identified issues

First of all, Tan (2022) means that the competitive nature of commercial logistics, including time constraints, schedule adherence, and travel stress, significantly raises the risk of accidents for logistics operators. This is something that ID1 agrees with and explains that one of the main issues is that items and pallets are placed in the wrong areas by personnel. This is caused partly by internal employees, but also by external people. The latter ones are not always up to date and aware of how certain pallets and objects should be handled, which then results in pallets and components being lost. ID1 explains further that the lack of employees is also an issue. There are less personnel now, but the tasks themselves have not decreased. This itself leads to human errors due to stress. The workers have a small time frame that does not give the time they need to complete the tasks in the best possible manner.

Furthermore, Eroglu and Hofer (2011) explain that lean management of inventory is associated with low levels of inventory. Several respondents mean that the basement should take on such an approach, since it is currently more filled than it should be. For instance, ID1, ID2, ID3 and ID5 all agree that the lack of space to store new redundant components in the basement is a major issue, which is not aligned with effective inventory management (Eroglu & Hofer, 2011; Nasim et al., 2016). The reason for this is that the employees have to find places in smaller areas and try to squeeze the pallets into areas that are already filled with other pallets since there is a lack of space in the basement. The consequence of this is that the space becomes even more filled and unstructured, which moves away from having a lean inventory management.

ID2 is sharing the same thoughts as ID1 by stating that when a worker finds the desired pallet, it often requires movement and rearrangement of other pallets to access it, and many times the worker, that already took a lot of time searching for the pallet, has not time to put everything else back as it was. This implies that the event “Difficult to find pallets” also means an issue of unnecessary time, even though it is not included in the network (Figure 6.1). Time is thus also an issue connected to “Not enough space” and “Deep stacking”, since those also demand extra time from the employees. According to Aro-Gordon and Gupte (2016) time is an essential part of inventory management and cost optimization . The collected statistics also show that handling time is the major cost of a component's time in the factory (Figure 5.1). Combining those two factors leads to the conclusion that the extra time

it takes to search and rearrange in the basement is an unnecessary expense that would disappear if cutting time was prioritized.

Continuously, the level 4 issues “No one is responsible” and “Production channels return too much” have very different characteristics. The latter is, in this context, a very concrete issue with many connections, and will further be elaborated in the next section about solutions. The first one is, on the other hand, more abstract, and therefore difficult to attack alone. However, that the responsibility is unclear must be seen as a major issue. It is a major issue for the obvious reason that when no one is responsible, the development of the basement stagnates. According to ID5 the basement is, however, everybody's responsibility, which also goes hand in hand with a lean warehousing process, since that requires continuous involvement of all employees (Anđelković et al., 2016). The identified issue, however, alludes to the opposite of continuous involvement. Therefore, to assign someone as responsible for the structure of the basement as ID1 proposes, could be the first step of making employees more involved.

The issue “Too many temporary solutions” is identified as a level 1 event but ID2 means that it is a big issue in the basement that is difficult to get away from. What is implied is that the temporary solutions eventually become permanent, which require new temporary solutions. According to Anđelković et al. (2016) this is a form of improper use of space and therefore a type of unnecessary inventory, since the temporary solutions take up more space than what is needed. At the same time, Nassim et al. (2016) mention a term called slotting, which is simply about improving the structure of a company's inventory. Which in this case would mean to get rid of the temporary solutions. Taking into account the respondents opinion about the structure, one way could be to divide the warehouse areas by production channels (ID1, ID2, ID3), or to divide it by component type (ID1, ID2).

Lastly, other issues connected to the basement are, for instance, “Doubtful internal communication between sections” and “Projects do not work as they should ", but they are both identified as independent issues in Figure 6.1. It could, however, be argued that they both contribute to some of the lower grade issues, but since the connections are moderately vague, they remain “independent”. Also, due to these events´ independence, an improvement or mitigation of their problematic characteristics would be helpful for the structural deficiencies, but not as impactful as approaching other issues with more connections.

6.3 Possible solutions

Instead of only focusing on the analysis of how problems are related to each other, counteractions against the problems also should be analyzed. Consequently, the counteractions´s impact depends on the attacked issue´s connections. The analyzed possible solutions are primarily thereby attempts of solving events with many following events. The succeeding headings will explore the possible outcomes of these solutions, with consideration to the events involved.

6.3.1 Implementing a formula as a decision support rule

Examining the events flow network (Figure 6.1), many issues are in some way connected to the issue "Production channels return to much", which in turn depends on the two fundamental issues. Thus, the first question that arises is directed towards the production channels. What should be done to minimize the transportation of pallets down to the basement in the first place? Secondly, if directing the question towards the current lack of space instead, what should be done to clear out the area? Figure 6.2 shows that a formula could answer both of these questions, and hence mitigate other connected events as well.

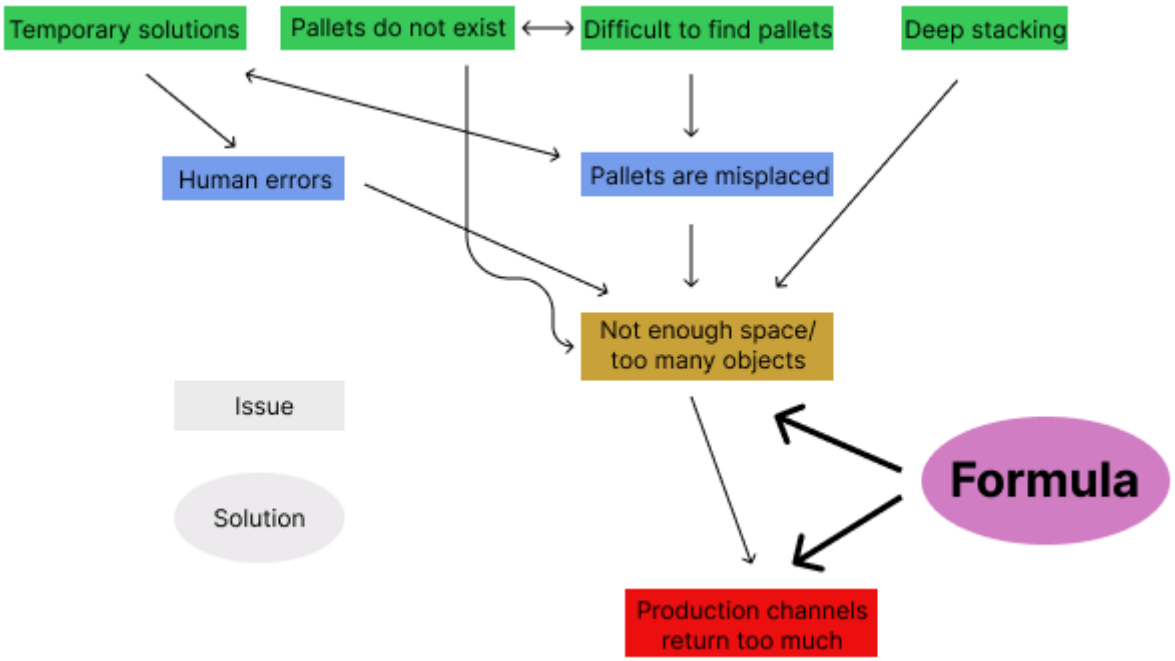

Figure 6.2: ***A formula as a solution.***

The figure shows where a decision support rule could be placed in the events flow network, and accordingly also which events it can affect.

However, Anđelković et al. (2016) mention eight different wastes that can hinder a company from achieving a lean way of working. Some of these can be compared to the issues identified in the basement of SKF´s D-factory. Firstly, "overproduction" could directly be connected to the production channels´ return rate, where no overproduction will remove the transportation of redundant components to the basement. This is however, a waste that is difficult to remove since shifts in production and the scrap margin is a company method for satisfying the customers. The same applies for "defects", which according to Anđelković et al. (2016) can include errors during processing or handling of materials. ID4 means that the scrap margin is the initial reason for redundant components but that a strategy without it can make the number of redundant components even larger. This is because the production channels then become very vulnerable for errors. Now, a channel perhaps produces one component too much and that component becomes redundant. Meanwhile, if the channels had the goal of producing exactly what is demanded and one of the components comes out defective, all the other ones will be redundant.

Furthermore, unnecessary movement, which according Anđelković et al. (2016) imply inefficient routing for employees, could be connected to the extra time it takes for employees to search for pallets in the basement. Unnecessary movement in this case can thus also be derived to unnecessary inventory (not enough space/too much time), since that is the reason for the extra time it takes for employees to find the intended pallet. What figure 6.2 is trying to highlight is that a decision support rule, a formula in this case, can minimize the amount of unnecessary inventories, and hence make pallets easier to find, to agree better with the systems, minimize human errors, avoid deep stacking etc. What also should be brought up for discussion is the waste "transporting", which includes unnecessary internal inventory transportation (Anđelković et al., 2016). As Figure 5.1 exhibits, labor costs for transporting the pallets are much greater than the holding costs for a pallet or a half pallet (approximately 4.6 times more expensive for one minute of handling a half pallet than to store it in the basement for one day).

Anđelković et al. (2016) also point out that lean warehousing is a philosophy that calls for continuous, methodical, quantitative, sustainable improvement of the warehousing process with the full involvement of all employees. ID3 agrees that there should be a continuous implemented philosophy of how the materials should be handled in the basement. Calculating how much room the materials in the area need to be structured is the first step in increasing

the basement's useability. Another solution to the problem is to remove all the pallets that are no longer useful, which will free up a lot of room and enable usage of the entire surface. To recognize when a pallet costs more than it is worth, one needs to have some kind of foundation or decision-making tool (ID3).

Above implies that one solution for the initial mentioned questions could be to calculate if the holding costs exceed the actual value of a pallet over time. What then demonstrably also should be included into the equation is the costs for the employees handling the pallets, since that cost is so much higher than the holding costs. Which according to Anđelković et al. (2016), should be considered as a waste.

6.3.1.1 Presentation of a trade-off formula: a rule to decide which pallets that are worth keeping

To calculate the costs versus value of pallets in the basement, some sort of formula would as mentioned be suitable, both based on the meeting discussions, interviews and according to Gurtu (2021) who discusses involved costs for holding inventory. Therefore, that is what has been done. The formula (Figure 6.3) is a mix of variables, mainly chosen and collected from SKF´s suggestions. It is also based on the discussion by Gurtu (2021) about what holding inventory actually costs, and inspired by Anđelković et al. (2016) who means that labor costs are 60% of total warehouse costs while space stands for 25% of the costs.

Additionally, the ratio between pallets retrieved and sent down differs a bit and when a hundred pallets have been retrieved, 121 pallets have been sent down. It also takes 7 times more time to retrieve a pallet, than sending one down to the basement. This means that a continuous pace and relation between the two directions should result in an even more filled, disorganized and time consuming area in the future. The time relationship will, however, be decreased if the area would be better organized since the results from four out of five respondents show that searching for pallets takes unnecessary time. Hence, something needs to be done to at least even the score, since moving something from point X to point Y as efficiently as possible is the primary function of logistics (Moshood et al., 2021). To do this, two paths are possible, make more pallets go up again, or to send less pallets down. Both the time- and amount relationship points the direction towards the latter. The formula presented below, is thus an attempt to approach the issue in that direction.

$$If;\ PV < LC(HTr + HTs) + HC(days) = Do\ not\ keep$$

Where:
PV = Pallet/half pallet value
LC = Labor costs/employee/minute
HTr = Handling time for retrieving a pallet/half pallet from the basement (minutes)
HTs = Handling time for sending a pallet /half pallet to the basement (minutes)
HC = Holding costs for a pallet or half pallet/day (based on a total holding cost for the area)
days = Number of days the pallet has been in the basement.

- ★ *"HC" and "days" are variables not included for pallets that are not sent down yet, and therefore only variables included for pallets that already are in the basement.*
- ★ *The function* $LC(HTr + HTs) + HC(days)$ *is based on an average handling time during the period January 1 to March 1. Labor costs (LC) is based on the average costs for a factory worker during a year. The variables thus present the handling costs for handling a pallet or half pallet, which is crucial when determining the actual costs of storing a product (Gurtu, 2021). HTr is a cost that has not happened yet but it is still included since components need to be retrieved from the basement to be included in a new final product.*

Figure 6.3: ***Value vs costs formula.***

The formula presented is as mentioned an attempt of understanding how many pallets that cost more than they are worth at a current-state. It could however also be suitable for supporting future decisions about pallets even before they are sent down, to minimize unnecessary handling costs, which as mentioned is the highest variable in the formula. The formula leads to a new small data collection, a simple test of how many pallets currently cost more than they are worth in the basement. Additionally, to put the figures in a context of different scenarios, one test with variations to the actual values is also conducted. The different outcomes are presented in the figures below.

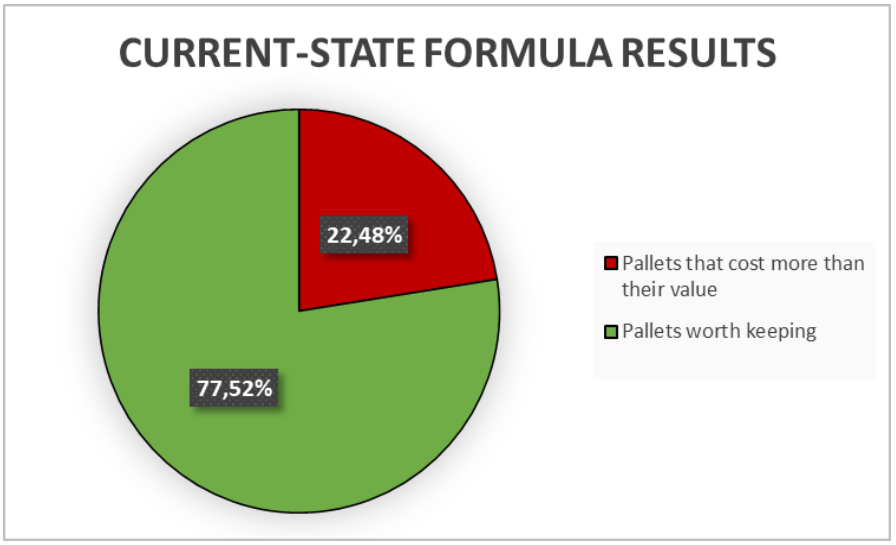

Figure 6.4: ***Current-state formula results.***

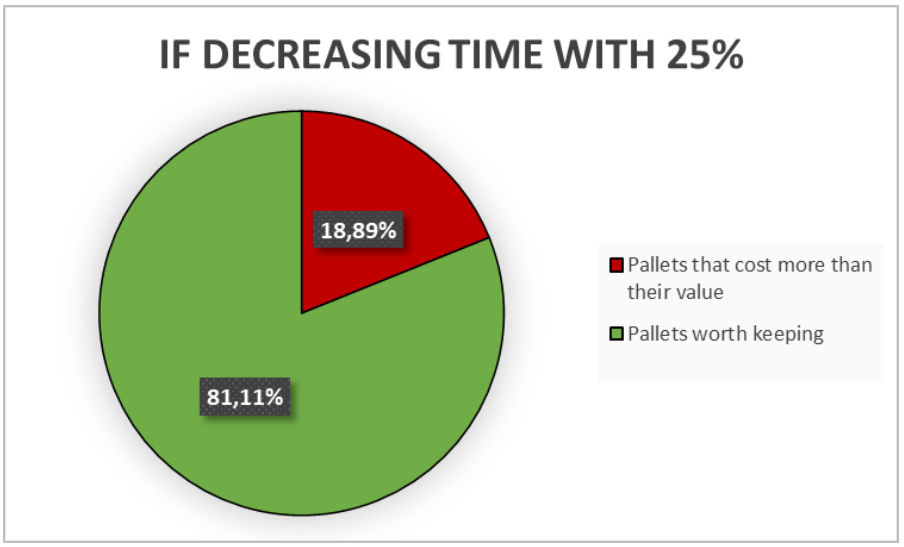

Figure 6.5: ***If decreasing time with 25%.***

Figure 6.4 shows that there currently are approximately 22.5% pallets or half pallets in the basement that cost more than their value. Since time already is identified as a large part of the pallets´ costs, the formula also tested a situation where the handling time decreases by 25% (Figure 6.5). Decreasing the handling time by 25% will demonstrably also decrease the amount of pallets not worth keeping with more than 3.5% (Figure 6.4; Figure 6.5). That number might appear small, but in the context, it is in fact a high number. The value of pallets varies but some are worth tens of thousands SEK, while the handling and holding costs are not close to these numbers.

Accordingly, some of the pallets are on the edge of being valueless in the near future. It also means that time, which according to Aro-Gordon and Gupte (2016) is an essential variable for inventory management, has a high influence over how the redundant components should be managed. Consequently the basement´s structure and the time it takes to handle pallets have a two-way relationship. A better structure in the basement will decrease the time for employees and a faster pace from employees will keep the pallets´ costs down. To connect this with Kumar (2016) who discusses inventory levels, the two-way relationship could be the answer to what the ideal inventory level of redundant components are.

Furthermore, the comparison between Figure 6.4 and Figure 6.5 shows that pallets should be held in the basement for a longer time if the handling time decreases, since handling costs are so much higher than holding costs (Figure 5.1). That in turn goes against the entire idea of lean inventory management, since lean should mean that holding inventory is a liability and not an asset (Nasim et al., 2016). In the end this means that less components equals less time to retrieve pallets hence also less handling costs. Less handling costs in turn means that the pallets cost less to hold (according to the formula) which also means that more pallets are worth keeping. This may seem like a dead end, but it does not necessarily have to be.

At current-state, 22,5% of the pallets should not be kept in the basement. The first step thereby becomes to get rid of these pallets. Then, there will be less pallets in the basement, and accordingly easier to make it more structured, build pallet racks, get rid of deep stacking etc. In the next sample, the average handling time should, according to this analysis, have decreased as well, which also keeps aligned with Eroglu and Hofer (2011) who mean that one outcome of lean inventory is decreased labor requirements. This means that the share of handling costs as a part of the pallet costs will have decreased. What also needs to be included in the equation is the pallets´ values. The 22,5% removed pallets from the basement, was demonstrably also not the most valuable. This means that the pallets that are not removed, will increase in value for each time the handling time/costs decrease. This is only applicable if handling costs is viewed as the only cost of a pallet, which it is not. It is, however, the by far highest cost for this case, and also for warehouses in general according to Anđelković et al. (2016), that appoint labor costs as 60% of the total warehousing costs.

The formula is conducted as a simple test to evaluate the current situation. If taking it into account for future decisions, it would however preferably be developed as an automatic

data-driven decision-making tool, since Brynjolfsson et al. (2011) and Berndtsson et al. (2018) mean that makes companies reach higher performance levels. That data-driven decision making tool would preferably be placed already in the production channels, so that components that cost more than their value are not sent down to the basement in the first place, which reduces all unnecessary handling costs. If placed in the production channels, a developed model should also calculate which day a pallet´s cost exceeds its value, and base decisions on that. Hence, the already highly automated factory could be an asset for the future. The automated environment can help the non-automated flow with decisions without making the flow itself more automated.

6.3.2 Implementing AGVs as a solution

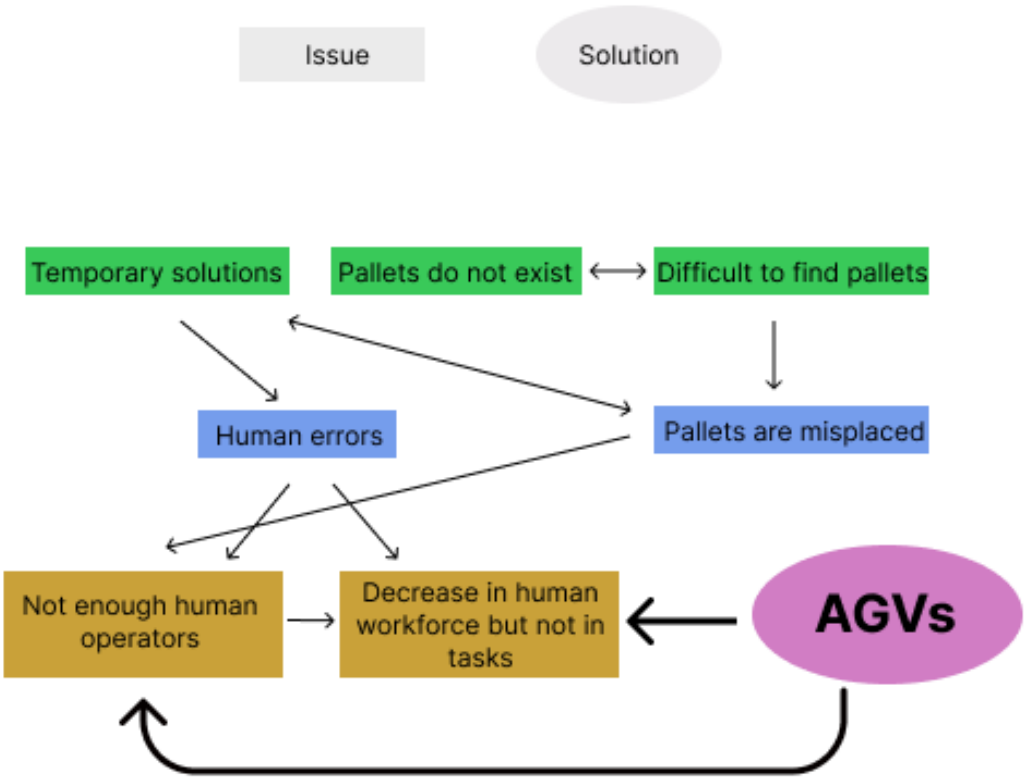

Figure 6.6: ***AGVs as a solution.***

First of all, the map over the basement (Figure 3.1) demonstrates that the investigated area has more space that does not include AGV-lanes than the other way around. At the same time, the flow of products that are not redundant, is dominated by AGV-movement. Therefore, one solution could be to expand the responsibility of the AGVs in the basement, which ID2, ID3 and ID5 agree with.

Nasim et al. (2016), Eroglu and Hofer (2011), and Anđelković et al. (2016) explain that inventory reduction is a routine task at work, it saves money and it places emphasis on raising performance levels and reducing or eliminating some activities. However, ID1 thinks that SKF has not reduced or removed any objectives that the factory workers handle during their shifts even though the amount of personnel is decreasing and the area focus is larger. Both ID2 and ID5 agree that AGVs can be a tool for reducing and eliminating activities for the factory workers. With human workers there will always be at risk of errors occurring, this could be the pallets disappearing or being placed in areas that no one can find. To connect this with the wastes Anđelković et al. (2016) present, "mistakes" which primarily refers to inventory inconsistencies, can in this case be connected with the human errors. Accordingly, using AGVs instead of human workers will reduce one waste, and take the flow one more step towards a lean environment.

However, Zion et al. (2020) state that an AGV implementation is difficult, and the reason for this is because of constantly shifting layouts, and the massive need for extreme adaptability. ID1 states that AGVs are a great tool that makes operations more efficient, but that they have not reached their full potential yet. In certain situations, they are more of a burden than a helping hand, and if one gets stuck behind another, it will affect the entire fleet which will lead to no tasks being performed by the AGVs (ID1). Both ID2 and ID5 explain that in order to have a fully implemented automated system, the vehicles themselves should be able to place pallets in pallet racks. The reason for this is that it is easier to track and place a certain component somewhere if there is a designated spot for it.

Berndtsson et al. (2018) mean that businesses should prioritize solutions that should provide their staff with easy-to-use tools so they can be able to work as effectively as possible with their surroundings. ID1 explains that the factory was built in the 1950s, this means that the floors are not well suited and built to handle autonomous vehicles and that the in-house programs are not always communicating with each other. Forklift drivers are using systems that in some cases are not communicating with the systems that the AGVs are using. This means that it can be difficult for the factory workers to work effectively with its surroundings, which Berndtsson et al. (2018) value. Furthermore, when AGVs are starting to have issues, it quickly becomes an issue for the employees as well. In order for the chemistry to be well-suited in the basement, some structural changes are required according to ID5.

These changes are implementation of pallet racks, smaller pallets, better and bigger storage places.

An issue from Figure 6.1 that thus also could be included in Figure 6.6 is “Systems are not integrated with each other”, since that issue affects how AGVs could operate in an area. In addition to the doubtful cooperation between systems in an AGV-context, the alleged poor integration between systems also refers to the loss of data when transferred. For instance, ID5 explains that the different systems do not cooperate perfectly, which means that their products can move between different systems without keeping all information aligned with them. Hence, there is no way of knowing how old some components are. A countermeasure for this could then, in accordance with Berndtsson et al. (2018), also in this case, be to enhance the “easy-to-use tools approach”. Which simply means to make their digital tools more manageable, to improve the possibility of new insights (Berndtsson et al., 2018). Making the systems more integrated will accordingly also make issues such as “Deep stacking” more manageable, since both ID2 and ID5 mean that it is the systems that allow employees to place pallets where they should not be. The easy-to-use approach for an AGV-solution and to make systems more integrated are thus connected. Integrating the systems better will enhance the use of AGVs as a solution. In other words, if their systems get more integrated, it will be easier to implement AGVs, and thus all issues in Figure 6.6 can be affected.

Another issue, which is identified as independent, is “Projects do not work as they should”. It is independent in terms of how it affects other issues, but it could however be an issue to attack for enhancing an AGV-solution. This is because it, just as making systems more integrated, would make it easier to have AGVs handling the redundant components. What is implied is that projects conducted by both external and internal personnel many times do not take into account all the other things in the area that they affect. For instance, ID2 means that projects often are viewed as individuals, but that they tend to affect the entire environment and not just the aim of the project.

In addition to above, ID1 emphasizes that the current AGV-handling often face obstacles in their routing due to unfinished projects. It could be both projects conducted by external people and internal. One example is the implementation of pallet racks, which takes more time than needed, and accordingly make the area more difficult to operate in as an employee (ID1). These project deficiencies obstruct the possibility of adaptability, which is crucial for

implementing AGVs (Ziun et al., 2020). This means that making projects more considerate of the entire environment, and to complete in a more organized manner, could enhance AGVs as a solution. This is because AGVs will face fewer obstacles and project aims will not interfere with their operations.

Continuously, Ghobakhloo (2020) explains that industry 4.0 is what allows different machines and types of materials to interact with one another in the environment surrounding it. Berndtsson et al. (2018) imply that in order to be more aware, and to fully use gadgets and systems in industry 4.0, it is vital to focus on analytics. Organizations can analyze what has happened in the past with different descriptive analytics, and also predict trends that will occur with previous data as well. ID5 is aware of this and explains the importance of in-house programs that are being used for the AGVs. These programs can control and display the use of the vehicles. It gives a view of statistics and showcases issues that can be analyzed. The system can create different charts to give clear views of upcoming errors, and you can log all the problems and then pass them on to the personnel in charge of the implementation for the AGVs.

ID5 explains further that the data can show up to one month of statistics and one week's playback. This information can also be connected to personalized applications, which makes it easier for the factory workers to send information and logs to suppliers, since these applications can be downloaded to several devices which in turn can be used by the workers themselves. This information can also be used in BI and advanced analytics which Sharda et al. (2014) and Valacich and Schneider (2018) explain are vital to support different decisions within the organization. It is explained that BI tools give an understanding of what has happened (Sharda et al., 2014; Valacich & Schneider, 2018), which can be viewed with previous data through the in-house programs that ID5 mentioned. The same goes for advanced analytics, different charts that give clear views of upcoming errors shows why certain hick-ups and issues tend to happen. Which in turn is aligned with BI´s characteristic of facilitating a decision-making process by transforming data into useful information (Tavera Romero et al., 2021; Ain et al., 2019).

Additionally, AGVs can in some way be described as coexistent with humans at the current state (Wang et al., 2019). Even if the warehouse of redundant components is free from AGVs, they both exist on the floor of the basement (see Figure 3.1). It could also be argued that the

relationship between them is partly interactive, at least in one direction since employees need to assist AGVs if they encounter some kind of obstacle (ID4), and physical contact between humans and robots is one definition of an interactive relationship (Wang et al., 2019; Matheson et al., 2019). Accordingly, starting to implement AGVs in this area will change the relationship between humans and AGVs. Even if an implementation can have the goal of being fully automated, it is nothing that is done overnight. Therefore, the relationship will at some point be collaborative, which implies humans and robots have tasks that require the other to perform (Wang et al., 2019; Matheson et al., 2019). This means that an AGV implementation can generate a bottleneck for the flow, since humans cannot be as accurate as AGVs (ID1), and that human errors are the main factor for logistical mishaps (Tan, 2022). In the end, if the redundant components flow becomes fully automated, the risk of human errors will nevertheless be minimized both according to ID5 and Janssen et al. (2019), where the latter mean that that is the reason why humans must eventually devote themselves for the change. The reduction of human errors will, as mentioned, reduce the lean inventory waste "mistakes" (Anđelković et al., 2016).

Consequently, AGVs could be the solution for handling redundant components but such an implementation requires consideration of many other areas to maximize the outcome. An implementation will decrease the workload for the human forklift drivers, reduce the amount of human errors occurring, and hence make the area more structured, as Figure 6.6 is trying to demonstrate. In turn, this will decrease the extra time it takes for workers to search for pallets, and minimize the labor costs. However, the implementation will face obstacles and make the situation worse if not conducted correctly. For instance, that the facilities are not shaped to handle AGVs is an issue that could point in the opposite direction. Nevertheless, even though the AGVs have their issues for the consisting materials flow, four out five respondents think they are helpful (ID1, ID2, ID3 & ID5), and three of them also think they could be helpful for the redundant components´ flow (ID2, ID3 & ID5).

6.3.3 Summary of suggested solutions

In summary, the analysis of potential solutions to the basement´s issues, highlight different flows of events. These flows are, as stated, connected in one way or another. The suggested solutions have the purpose of solving issues with many following events to impact as many issues as possible. Therefore, the two main solution suggestions, to use a decision support

rule and to automate the flow in the future, are potential solutions that affect a flow with many following events. However, since the events are all connected in some way, it should also be emphasized that approaching one single event, will affect all the others, even if this events flow network has no connective arrows between them.

7. Conclusions and Contribution

In this last chapter, the conclusion of this thesis will be brought forward as well as answers to the research questions. Contributions to research and suggestions for further research are also presented.

In conclusion, the non-automated flow of redundant components in the highly automated environment, has many issues. The first research question "What are the problems for the management of redundant components in the studied area?", is thereby answered by the events flow network presented in the analysis. The issues are, however, of different character and should be managed depending on their characteristics and connections. This means that the issues can be mitigated to varying degrees, with varying effects. The first countermeasure is to limit the amount of things in the area, which can be performed by using a rule that decides which pallets that, in fact, are redundant. For the future, such a decision support rule could be used to make decisions about redundant components even before they are sent down to the basement. Another prospective solution could simply be to automate this part of the factory as well, by replacing human workers with AGVs for the tasks that flow entails. However, this means that one way of managing a non-automated flow is to make it more automated. If instead focusing on how the actual non-automated flow should be managed as continuously non-automated, the decision support rule is to prefer out of the two main proposed counteractions. Even if the researched company aims to take the automation way, the rule would be the first step to pursue that path.

Therefore, the short-term part of the second research question, "How can the identified problems be opposed?", has a simple answer. The first steps are to decide which pallets that are useful, and which are not. The second step is then to decide what to do with the pallets. The third step can then be applied to the long-term part of the question. To keep streamlining the redundant components flow in the future, the decision support rule can still be helpful and reduce unnecessary holding and handling costs, which also removes pallets that cost more than their value. Implementing AGVs for this flow as well, could be helpful in the future, it will have its complications, but the already automated environment will simplify the process.

Thus, the study contributes to the research by showing that the answer for all obstacles in an automated environment is not necessarily to automate further. The technical environment could, however, enhance the development of a non-automated obstacle. The time limitations

of the study also suggest further research with more concrete answers to the suggested solutions. Hence, to expand the knowledge of this matter, research with focus on how an automated environment will enhance or impair non-automated parts of the environment is the reasonable next step to take.

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Appendix 1 : Transcript ID1

Describe your current role in SKF
I am a forklift driver in the D-factory. I work within factory logistics.

Does the basement play a role in your line of work?
Yes it does.

How well do you think the basement is helping your line of work today?
Doesn't work at all in my opinion.

Why is the basement such an issue?
One of the main issues is that items and pallets are placed in the wrong areas by personnel. With different projects that are ongoing in the basement, external personnel that are not a part of SKF move things around which are not connected to our system that we work with. So to summarize, different objects and pallets are not where they are supposed to be, and that is the main issue at this moment.

Do you think that the basement is not as structured?
Yes. The problem is also that we do not have enough space to store new redundant components in the basement. The issue with this is that you tend to find places in smaller areas and try to squeeze the pallets into areas that are already filled with other pallets.

If you could choose, what would you change with the basement in order for it to be more efficient?
One of the main things is to make sure that the ongoing projects in the basement need to be fulfilled at a higher tempo. External companies enter our basement and they build new pallet racks for us to use, but when they've started the first one and finished it, they don't come back until four weeks later and then start to build a second one. This itself makes the basement much more unstructured there and harder for us to work in. This limits our workspace even more, which is a major issue since we already have issues with free space for new redundant components.

It's also important to mention that in my shift team, we do not have personnel to fully focus on the basement the way we want to. This means that we don't have the time to look for certain pallets that we might need in some cases. The AGVs are also a major bottleneck for our operations. This is because if they tend to have issues, we ask forklift drivers to handle that as soon as possible. This means that the current search we have for a certain component that is needed in the material flow will be even more postponed.

It's also important to mention that there is a human error factor in this. Our own personnel sometimes put the components in the wrong locations, which then becomes more difficult for us when you need to find them later on. Some explanation to this is because the basement is really tight in some areas, your turn to place the components in an area that is easier to access with longer forks on the forklift. I also feel that sometimes forklift drivers are being misinformed about new things that we need to consider and handle during our operations. I also think that stress is a major factor in human errors. Since time is so limited and the components are needed in a quick manner, it's reasonable to understand that stress is something to consider when making human errors.

I want to add that I fully understand the strategic decisions that SKF has to make considering reducing the amount of personnel for the sake of automation in order to stay both competitive and to keep the factory here in Sweden instead of somewhere else. The issue in this case is that they have not reduced or removed any objectives that we are supposed to handle during our work even though the amount of personnel is decreasing and the area focus is larger. We have just as much to do as before but now with lesser people. As it looks today, it would be vital to have someone that is only dedicated for the work in the basement area. I would say that SKF has a vision of how the future will look but the actual route to get there is sometimes hard for us to cope with and understand.

How do you think the written off or discarded pallets should be handled in the basement?
I have actually myself found pallets that are written off in the basement and the reason for that is because someone has simply not found it. One of the main factors that this occurs is when external companies have certain projects in the basement and then move pallets around without letting us know or making those changes in our systems. This makes us completely unaware of where certain components may be since it's not SKF personnel that have made changes, it's impossible to know where it's been moved. When we do not find these pallets we write them off in our own systems. What that happens is that these pallets need to be put back into the systems which is not an easy thing to do and it takes clearance as well. There's also situations where the production channels themselves go down to the basement and simply pick some of the components on the pallets, which is also problematic since they don't change anything in the business intelligence programs. This leads to the systems showing the wrong amounts of components since others don't really bother to change. I have no issue at all with personnel at SKF going to the basement to pick up components in a very rushed matter, time is money and we need to produce at a higher rate, but to simplify it for everyone it's important to make the changes in our internal programs as well as the changes that are made in reality.

What do you think of automated guided vehicles handling the redundant components?
In my personal opinion, I really prefer human beings working in this environment. There is of course a great thought behind AGVs, but since they are more of a burden right now in some scenarios, it's tough to be as efficient as they can be. On the upper floor I see that there are a lot of automated guided vehicles, and I personally don't think that the more they are the better, they often get stuck behind one another and if one doesn't work it will affect the entire fleet. If we however look at the basement level, we only have four of them, that is still a major issue for us since they tend to have issues as well even though they are not as many as upstairs. It's also important to mention that this factory was built in the 1950s, so these floors are not really built to handle these types of vehicles in the best possible manner. So in the big picture for me, I don't really see these vehicles being so efficient and effective in the basement. In order for them to work we also need pallet racks, and we don't have the capacity in the space to do that, and even if we could we still have too many pallets in the basement so they all wouldn't fit.

There is a possibility that an automated guided vehicle can place pallets after one another on a straight line, the issue with this is that as humans don't have the lasers and the measurements to be as exact as these AGVs. This means that AGVs will have difficulties picking up pallets from spaces that humans have placed pallets in.

Do you even think that there is a possibility to implement more AGVs in the basement then there is today?

No, I don't think so. I don’t think the floor is suitable enough in the basement for these types of vehicles and they were also most likely in some scenarios block each other and create more hiccups in our material flow than they would create efficiency. If this was possible, we would need someone to be in the basement at all times to have all these vehicles and pallets on overwatch, and that is something we do not have.

Is it hard to get the redundant components in the basement back into the materials flow of the factory?
It all depends on what type of component it is and what production is suitable for. Some components are more regular than others and therefore they are often being put back into the material flow in a quicker manner than some other components that are more special and are only used maybe once or twice a year. But this is where my thought process stops, I get my orders on my computer and then pick up that pallet that they want. I simply work from the orders that I get.

Do you feel that the AGVs have in some way actually facilitated the workload in the basement?
In today’s time, the answer is no. It’s simply because they are not working the way they are supposed to and they are creating congestion in the basement and it leads to us workers needing to have more workloads than necessary. It’s very rare that AGVs are working the way they are supposed to for a longer period of time without having some sort of issue. I would like to have someone being brought in on overtime and just simply having one objective and that is to clear up the basement. Go through all the components and see what can be done and if they are out of the system or maybe if they can be used right away. It would give us a well needed structure in the basement. I also have a theory that the network isn’t as accurate and precise in terms of connection in the basement. There have been times where I’ve been putting certain components in different locations but later on they show something else in our systems. We also have issues where the programs that are suited for the automated go to vehicles are not communicating with the systems that us forklift drivers are using, so I personally also think that the AGVs themselves are not working in their best environment.

I am completely fine with these vehicles operating in the basement, but I can’t stress enough the importance of actually finishing these projects and making sure that the routes that they are working on are fully overseen and finished. The same thing goes with the pallet racks and other projects that are ongoing in the basement or in the factory. I believe that they can be done in a faster and more complete manner. An example is the pallet racks that I mentioned previously. They implemented one of them and it took them four weeks then returned to the factory to make a second one. I am not an expert on project management, but I strongly believe that things could be done in a faster and better manner.

Any thoughts of solutions to the basement issue?
Dividing our spaces in the basement towards certain production channels could be useful. This would at least minimize the risk of not finding pallets since we have distinguished areas for certain production channels, so if they wouldn’t find something we knew that it would be on the specific area. It could also go the other way around if you don’t find the necessary space, you could always place that component on a certain area where you know a certain production channel will use it later on. I would also highlight that it could be a possible solution to divide areas into different components instead of different production channels. This could also make it easier to search and find pallets since you know that certain components are in certain areas. Also like I mentioned before, having personnel being brought on overtime just to try and structure the basement it’s also a solution to this issue since we can’t have someone full-time down there.

Appendix 2: Transcript ID2

What is your line of work?
My line of work is to make sure that everything is running logistically within the D factory. I'm also an employee coordinator which in theory gives me larger responsibilities I guess.

Is the basement a part of your work?
Yes

How do you think the basement is working today?
In my opinion it doesn't work at all, I see it as a dark hole. If I were to be more precise there are three major problem areas.

The first problem is that there are a lot of small temporary solutions that have been permanent. We have different locations in the basement that actually don't exist anymore. We have numerous new locations in the basement that are connected to previous areas that have been moved to a completely different location. To simplify, you would expect area three to be next to area two, but instead area three has been moved further away into another completely different area in the basement. This itself is from the beginning a temporary solution in order to utilize space in other parts of the basement, but the solution seems to be more temporary as more time passes. This makes it important for us workers to memorize where different locations are instead of using common sense to try and find them. (ID2)

A second problem that I would like to highlight is the difficulty in finding different components and pallets. There's also occurs in stacked areas where there are a lot of pallets close to each other in a high amount. In certain situations it's very hard to see which pair that you are looking for and this is also very time-consuming for us workers. Another issue with moving different pallets to find the one you like is that the pallets that are being moved might stay in another area since you don't have the energy or time to put them back into their ordinary place. So the issue is that there are a lot of areas that pallets are close together which makes them hard to find and then when you're supposed to put things back into place, there is a risk of not doing that the correct way.

The third issue is that we have certain places that actually don't exist in the physical basement but only in our systems. These areas were simply made for the purpose of temporarily storing certain goods, but the issue is that people tend to use these places because they do not have a certain limit in the amount of pallets that can be stored since it doesn't actually exist. This means that workers tend to put certain pallets and components in these made-up locations that only show in our systems and not in real life for simplicity purposes. This also leads to a lot of time spent in finding certain pallets since if they are in one of these made up places, they could actually be anywhere in the basement.

What would you have changed with the basements in order to make it more efficient for your work?
My first initial thought is to remove these areas that have deep stacking, I would instead use pallet racks everywhere because then a pallet would only have one exact place where we can be. Using a pallet rack means that you only have one designated spot for one pallet which makes it almost impossible to misplace. I would also have to implement a way of working where if something is supposed to be in a certain location in the basement, it has to be there with no exception whatsoever.

This means that it doesn't matter how many pallets you have to move to find some components, you have to put everything back where it is supposed to be no matter the time it takes. This is however not feasible today since it's a matter of space, which is something that we do not have in the basement. Using different pallet racks or taking up a lot of space and therefore limiting the amount of storage for our components.

Another option is to have different types of forklifts in the basement. They are variance where you have your forks on the side which makes it much easier to access certain racks. As long as it's organized and you know how to look in the best possible way is a minimal solution that should be applied.

Looking at a short term solution I would like to have these imaginary areas in the system removed so that we do not allow for people to place certain pallets in areas that can be anywhere. Also an improvement in the programs that we are working in where you can easily see which places that have more availability than others. Today is simply just a recommended place for the pallet to be put in and nothing more. If you want to see or try to fit it into another area you have to try that and then see if the system allows it or not. Another conclusion to be drawn is that the systems we use allow for laziness.

It's also worth mentioning that the basement isn't really standardized for pallet racks. There are plenty of pillars that hold up the roof and therefore limits the space for any type of bigger objects to be implemented into the basement. What is being said is that there are so many pallets and components in the basement that it's also really hard for us workers to find an actual spot. In certain cases I have been roaming the basement for 30 minutes plus just to try and find a place to put a pallet.

How would you handle written off or discarded pallets in the basement that are outside of the system?
It's an interesting thought, because we do have certain special components that are not common at all in certain productions. This means that it's completely normal for a pallet to be left in the basement for a longer period of time but it's also interesting to deep dive into why? You might need to think about opportunity costs, the basement is seen as a resource and if something disappears in the basement because of too many pallets, that leads to a direct cost for us to consider. So is it worth having something sitting around for two years instead of actually discarding the pallet and releasing more space. I also have difficulty seeing something that would be in the basement for five years to look attractive for customers and also the production channels to use. I assume that the reason that we've kept certain components for so long is because the value of them are greater for production and textually sell or discard the pallets.

Do you see a possibility for automated guided vehicles to handle redundant components?
Yes of course, if we were to get these AGVs to operate in a better environment with less errors occurring I do believe that it would be more efficient to have AGVs used instead of workers to handle redundant components. This could be made into reality if we were to implement pallet racks which are suited for AGVs. With having human workers they will always be at the risk of errors occurring, this could be the pallets disappear or are placed in areas that no one can find. This will probably not be as occurring with automated go to vehicles handling the inventory management. And in my opinion the greatest loss of having human workers is the difficulty in finding pallets and the risk of them disappearing. I believe that this will not occur when having a well implemented AGV system.

Do you believe that it's difficult to have redundant components in the basement put back into the material flow?
It completely depends on the component itself. We have a limited amount of slots for certain components, for instance grinded rings. Since we have eight hours of staging for a 24 hour period, it becomes a bottleneck and demands more intense labor. An issue with this is that since time is of the essence other production channels might prioritize the components on the upper floor since the slots are so limited and it's important to meet customers' demand. The downside is therefore that if it's difficult to find these components in the basement, by the time they have been found it could already have been too late and the slots are for the occupied. This means that the pallet will be set up to the upper floor back into the material so will then be sent down directly again since it wasn't found in time to take up the limited slots.

Another issue that is worth mentioning is when there are shifts in productions. Since we only have eight hours of staging for 24 hours, as a production channel where to swiftly change the components that are necessary, it will interrupt the entire process for us. This also means that it will be more difficult for us to use the redundant components in the basement and find them in a reasonable time when something is demanded right away.

How do you believe the communication is within SKF, are you up-to-date with the changes that are ongoing in both the basement and the production level?
It happens that certain changes happen outside of our system. It can be that a production worker rushes down to the basement and grabs a few components from a certain pallet without telling us or our systems about it. It's not occurring often but it does happen every now and then. This means that the communication must be better between us workers in the factory in order for us to know the actual balance of certain components. The issue with this is that we tend to work very lean, which means that the planners that make the actual orders are dependent on the balances that are shown in the basement, and if they do not add up with reality we are facing some major issues in our production.

Do you feel as if the automated guided vehicles are making the basement more efficient in terms of material flow?
I would definitely say that the AGVs do make a significant difference, but not as significant as it could be. But thanks to these vehicles we were able to handle fully automated production channels in the basement which we do not have the personnel to handle so therefore they are an important resource. However, we cannot forget that there are so many issues occurring with these vehicles that are very time consuming, but it does not change my opinion that it's more beneficial than issue related.

Do you believe that the ongoing projects are being handled in the best possible way in the D factory?
No, I do not think the projects are being handled in the best possible way and fully finished. I do not know the answer to why, if it's a budget issue or that you are simply satisfied with the results that are being brought forward. I feel as if every project is looked at more individually than as a whole for our factory. For me the factory is one big working machine, the personnel, the tools and equipment should work together as one big machine. But if we tend to move away from the entire perspective of a plan into a more individual level, things can quickly become very unpredictable. I don't necessarily think that the solutions are bad, I just think that these solutions will not work together.

An example is that a previous solution we had was to empty the containers with the layers that are holding the rolls with our forklifts. These containers were in areas where we could easily access them, but then when we all of a sudden start to implement automated guided vehicles into bigger areas of the basement with more automated production channels, these tasks are becoming much more difficult for us to handle. The space is more limited since AGVs are usually in the way, and we do not have the capacity to empty these containers when they are midway full , so therefore it's very easy for these layers to overwhelm the container and then fall out on tracks where the AGVs are on. This creates more issues and It's also important to add that these containers can become full very quick.

Any thoughts of solutions to the basement issue?
It's difficult to implement pallet racks and other major construction sent to the basement since there are plenty of occasions where I spend more than 30 minutes just to find a tiny bit of space for certain pallets. To me it's almost as if we have a fridge that is full of food but we're trying the best we can to squeeze a little bit more into it. I see a big possibility in dividing different areas to either production channels or components, it's just simple metadata. A solution is that if we divide areas into production channels, the system itself would not even let a certain pallets be placed on an area that it's not connected to its production channel, therefore the system would be very dummy approved as well.

Another solution would be to simply bring a pencil with colors and just color different areas that match with its production channel, might be a bit of a longshot but the point I'm trying to make is that the basement needs to be divided into some sort in order for it to be easier to find certain components and pallets both for us forklift drivers but also other factory workers. But once again, it's important to make sure that everything is correct in the systems and that it is matching the reality as well.

There is also a big demand for an inventory restructure in the basement to really make sure that we know what components we have down there and that might also release space for us which is very valuable at this time. I do believe that it's also the other way around that there might be scenarios where you expect to have certain components in the basement but the reality is that it's not there at all. A few years ago, we had a policy in the basement. The policy was that if a certain pallet wasn't found within 30 minutes, that pallet would be written off and therefore removed from the systems.

Appendix 3: Transcript ID3

Describe your current role at SKF.
I am responsible for the logistics within the D-factory.

Does the basement play a role in your line of work?
Yes it does.

How do you think the basement works today?
It works in a helping manner, but one of the main issues is the structure down there. The reasoning for this is the lack of space and also all the reconstruction work that is currently happening in the basement. AGVs are a helping hand, but it's obvious that when they start to have issues, it quickly becomes our issue as well.

If you had the choice, what would you have changed with the basement today?
First and foremost, a general knowledge of how much space we actually do need today would be very helpful. As of now, there are areas in the basement where it's difficult for automated guided vehicles to drive in, so the main focus is to try and utilize the space we have in the most efficient way possible. Having a holistic point of view, really looking through different parts of the basement that might be necessary such as other storage spaces that are not so much used that could possibly be torn down to release more space. You could also have certain rules when it comes to how long a pallet should be in the basement and if it surpasses that amount of time, maybe it could be scrapped or moved somewhere else. To also calculate the cost of saving a space in the basement versus releasing it for other pallets would be interesting to look at.

How would you handle written off or discarded pallets in the basement?
Is there a difficulty to say, certain components are more special and therefore they are not as common in our production, this leads to them being stored in a longer period of time than certain other components. When it comes to the regular components that are more commonly used, there is a good circulation of them going back into the material flow and being used in the first in first out principle. Also when there is a shift in the production, if we are missing one component, that leads to a lot of different components needing to be stored in the basement since a bearing consists of more than just one component. So if we have a shortage somewhere, it will lead to a lot of redundant components as a hole down into the basement.

What do you think about automated guided vehicles handling redundant components?
I think that there is definitely a possibility that that might occur. We have new channels in the basement set alarm pretty much only handled by AGVs, so there is definitely a possibility of them also handling redundant components with the right circumstances.

Do you believe it's difficult to have the redundant components from the basement sent back into the material flow?
No I don't personally think so, it's staged from the planning section of SKF. The issue is the time span from receiving the order to actually picking up the pallet and sending it back into the material flow because of the bad structure in the basement. So it's the lead time which is the main issue. So in a perfect world, having pallet racks in the entirety of the basement would be the best since it would be

very easy for the forklift drivers to know where the pallet is to swiftly send it back into the material flow.

Do you believe that the automated guided vehicles have facilitated the work in the basement today?
Yeah it's facilitating the workload in the basement. The AGVs are mainly handling the finished stocks and it is making it more efficient for us and not having to have a worker full-time in the basement anymore. However, it's important to mention that it's not as implemented as it can be today. There are still issues occurring, so we will hopefully see the major winnings of this implementation when the AGV flow is fully organized.

Do you believe that there is a clear communication to the forklift drivers that are working in the basement?
Yes, but at the same time they've been stuck in the middle. I took over as manager during this project of cutbacks and AGVs. So in some cases, I do feel like they could be much more aware than they are today. It is also difficult since I was not supposed to be a part of this project but then automatically became involved when I became logistics manager. It's also vital that at least one of the personnel within factory logistics has the access that they need in order to quickly put lost pallets back into the system and find them so they can swiftly communicate that with other factory workers so they know that the balance has changed.

Any other thoughts you want to add about the basement of potential solutions?
Yeah, the ultimate scenario is implementing more automated guided vehicles will be optimal, but that would also have to be in a world where they work in an efficient manner and therefore gather pallets from pallet racks. I am fully aware that there are certain areas in the basement where pallet racks are not feasible, so therefore you would have to have certain areas where pallets are close to each other but then it's important that it's clear and structured how they're handling that material.

A few years ago, we had pallet racks that were directly connected to certain production channels. That worked out fine back then because you knew that the pallet that you were searching for was at least in that area. It's also interesting to mention the elevators that are being used in transporting the redundant components. There is a lot of maintenance being done on them which also slows the forklift drivers in the basement. Maybe look at other solutions on how to get the redundant components up into the upper floor.

Do you believe that automated guided vehicles are working in the best conditions today in the factory?
The AGVs communicate through certain systems, and there are several occasions where the systems are not connected with the systems that the forklift drivers use. This itself makes the conditions much worse for the AGVs, and therefore makes systematic failure a reason for an AGV failure. So it's important to mention that it's not solely the AGV itself that is having disruptions, it's the systems surrounding it.

It's also important for me to mention that when there are calculations being made on how many pallets that are going to be put into the basement, it's not considering the fact that there will be shifts in the productions very quickly. These shifts are usually reasons why there are plenty of pallets becoming redundant components in the basement. The more redundant components, the more workload for the forklift drivers which obviously limits their time to do other tasks.

What are your views on the ongoing projects in the basement?
I can see that there is a lack of holistic perspective when it comes to certain projects. I feel as if the basement is not always prioritized when starting new projects and implementing new ideas into our factory. It would be interesting to have the basement as a single project itself so the entirety of it would have a great focus.

Appendix 4: Transcript ID4

Describe your current role in SKF
I am responsible for all the production planning in the D factory. It starts from a component that we have ordered up until a finished stock that is ready to be shipped to our customers and storages.

Does the basement have a role to play in your line of work?
Yes

How do you think the basement is working in accordance with your line of work?
The basement works fairly well. The balances are often correct and the pallets can be found. There is therefore a good validity in the basement. This means that when we are ordering components we are counting on the balances in the basement and it is also in line with our lean way of thinking. This is especially when the component or pallet is assigned to a certain area in the basement, that to us is a sign of the pallet actually existing.

Is there anything in the basement to make your work easier?
No, I believe that it works pretty well.

What's your opinion on handling written off and discarded pallets in the basement ?
Every year, we clear out any pallet that is older than five years. So we have processes for handling those types of components.

What's your view on how the automated guided vehicles are working in the factory?
This is not really my main area of focus, but what I can say is that I believe that it takes a lot of time for someone to actually help a AGV that is stuck or simply standing still. Other than that, I don't really have much to say concerning this matter.

Do you believe that redundant components from the basement are getting back into the material flow efficiently?
This is not something that I can answer, I do not see how this process goes.

Is there anything you would like to add?
I also do believe that there are more pallets in the basement than we can see, so some pallets can be written off while in reality they might not just have been found in the basement. So it's important to have good luck and to truly see what components are in the basement.

Appendix 5: Transcript ID5

What is your role?
My role here at SKF is at first hand, AGV responsible, so I run projects with them and make sure they're working. I am also a type of channel technician, where I´m responsible for 3 channels, the old assemblies. I´m present at their morning meetings and run projects there as well, so those are my main occupations.

Can you describe your materials flow from inbound to outbound?
Yes, how it comes in-> there we have two component inputs, we can start with the first one. There we have a truck that arrives, and then there are forklift drivers that empty the truck and put the components on a floor space. Later, they take the material from the floor and put in AGV- racks. So we have manual compartmentalization, and loads of input control in the actual stallage. Later, from the racks, there are AGV:s that retrieve and transport the materials to the channels, and from there, the bearings are created, assembled, I mean by that. Then they are sent through the elevator and into the deep stacking, which also is made by AGV:s. So the only manual work is the actual input in the AGV-stallages from the floor space. In the basement we also have another production channel, so their component input is in the basement. It is basically the same procedure, but more automated. It works directly, the external company that drives the trucks in SKF:s area, emptying their trucks and putting the materials directly into a system. So the manual work of putting in materials in pallet racks is gone, and AGV:s comes and retrieves directly from the system and puts it in pallet racks, to later put in another system. So that's how it works. But furthermore, that channel has its own elevator also, for finished bearings, so that's how it works.

What is the basement´s role?
The basement's role is where all finished material ends up, and also where the "returns" end up. Returns are cages, guide rings and rings. Rollers are sent back to the factory they came from again, so those are never placed in the basement.

How does it work in the basement?
I think the area for finished bearings works alright, but sometimes there are too many cooks in the broth. I think that GLC rearranges more than necessary. I think they are working sub-optimal, and I don't think they really know how the AGVs leave, in what order etc. So I think that could mix things up, but when everything works and the clearance goes well, it should run as water. Furthermore, I think that "returns" in the basement can both be easy sometimes, but also very difficult. And when it is difficult, it takes a lot of time. We have many areas that are overfilled. You can say, there is a lot of stuff in the basement, which is not so lean.

How does the basement affect your way of working?
Our work hmm. What I think would be very beneficial for us is to limit the amount of things in the basement, and to make sure that everything that is treated like "returns" shouldn't be. So, some kind of rule of what should be in the basement, and for how long. I would also like to have a better digital solution. I mean our system works to control the material, but I think the actual pallet positions in the basement are problematic. We have very much deep stacking, and I don't think we have any limitations concerning how many things that could be placed in each. I think you can stack how much

you like there, and I mean if you want to find a pallet at the back of the deep stacking, against the wall, you must spend at least an hour to empty the stack and retrieve the pallet.

How should the discarded and written of pallets be handled.
The system should say when it's time.

Who is responsible for the basement?
I think the changing progress is everybody's responsibility. So you do the right thing on your part. I could make better pallet rack spaces or deep stacking in the system, limiting the surface is something I could do. Then that the channels don't return everything, that they have little control over what should go down in the basement and what needs to be in the basement, and what can be thrown away immediately. Then it's probably possible to do some kind of inventory check, and then it's factory logistics (FL) that must take care of it. To ensure that; you highlight a lot to keep track of the channels' PSA type, so what is in the channel in the system must also be there physically. But I don't think anyone really sees the basement as theirs, I don't think FL sees the basement as their area, so I think they just put stuff down. So, I don't really know where the responsibility lies, that is, in terms of the factory, who takes responsibility for the basement, because I think that if you wanted to put in proper work from FL's side, you could do it. But I also don't know who owns the basement directly, as an area.

Can you explain what you mean by "returns"?
Returns occur when you grind rings, because then it is very difficult to know how many will come out as approved rings. And when you order from Supply Chain, you can also order a scrap margin. And then it is, in addition to the rings, or the stocks that are sold, that you get a certain number of percentages. I don't know exactly how it works, but say you must make 100 rings, if you have a 10% scrap margin, you get 110 rings. Then you can set up the machine with 10 rings that can then become scrap. But then you have to make sure that you can produce everything else. So if the machine were to run really well and you might scrap 2 of these 10 rings, then you get 8 rings that are not part of a production order. And those rings are returned later then. That is why there are returns.

What is your strategy for handling returns today?
I don't really know how they work in the different channels, but I do know that before in one channel, when the channels were put together, before the newest existed. Back then we had some internal rules on what was a return and what was not a return. I think we said less than 6 cages and less than 3 guide rings were thrown away. Thus, less than 3 bearings were discarded. But rings were never thrown away, because they were so expensive. But then it's also different, I think, channel by channel. The smaller the rings, the cheaper they are. And then I can imagine that it's easier to throw them away, because I mean, a pallet takes up just as much space in the basement, regardless of its value. But I don't really know exactly how it works in all channels.

Have AGVs made the basement more efficient?
I don't really know if the work in the basement has. It feels like they have created more work in the basement. They didn't manage any kind of.. of course, finished bearings, truck drivers used to drive them, and they don't anymore. So, for that part they have made a difference. But the actual return handling and so on is the same right now, it isn't managed by the AGVs. So, they only run for other production channels. I wouldn't say they've made a super huge difference. It's just that you don't have

to run finished bearings anymore. But then I don't think it was the hardest work down in the basement, I think it's getting returns that is the hard part.

Can AGVs handle “returns” in the future?
Yes, it feels better that they could do that because I think it feels better. So, right now, there's a lot of human influence on where the pallets end up. You put them where there is room. I know there is a very big lack of space. So, if you had smaller pallets, storage spaces, and easier handling of the pallets, then I really think that the AGVs would be able to handle the returns. Now they can't do that because it looks like it does in the basement the AGVs can't run. But, absolutely, they could do it in the future, if you take care of what goes down in the basement.

Is it difficult to get "returns” back in the material flow?
I don´t work with that fundamentally, but those times I have had to do it, it has worked without any problems.

How do your digital solutions for controlling AGVs work?
I think I use Fleetsync the most out of everyone in the entire factory. I use it mostly to find deviations in the individuals. I can hear something like "it's wrong with the AGVs, they can't handle this and that". But then I can see a certain percentage, if any AGVs stand out. You can kind of say "The AGVs have stopped here 1 million times" to me. Then it's very hard for me to interpret it, is this as big a problem as people say? Then I can check in Fleetsync and get it in black and white, is this a problem or not? So, I get a lot of statistics from FleetSync. Then you can make your own charts and stuff, for example we had problems with charging before and then I got bars for each day when there was a lot of charging error, and then I could go back in time and see what had happened during that time. So it's a good and easy system to be able to log all the problems and then pass them on to Toyota. So that's how I use fleetsync. I use playback - the function very much to collect data, when the AGVs flips out.

- **How much can you see?**

It's a week, and then statistics can be seen for a month. So, one month's statistics and one week's playback. And then we also use our own app where the operators can log deviations with the AGVs. So, if they see that the AGVs are standing and alarming in every place every day, but I might not see it, because I'm doing other things. Then they can take a picture of the AGV, write what number it is, where it is and send it to us through the app. So we sit there every week and go through all the inbox, then we log that problem and then we pass it on to Toyota as needed. Then they can come here and fix the problem. So those are the two ways we use to find issues, that's Fleetsync and the AGV app.

Describe your view of FIFO here.
I had a meeting this week about FIFO, we have had problems with rust and then we want to make sure that FIFO is really followed. And you notice that the different channels do very differently. For one and two it is SC who asks FL to pick up the rings, I understood that as. But in the third, fourth, fifth, it is the grinding department that makes sure the rings come up. So, they order up the rings which FL then picks up and then it's the grind that makes sure they get into system 2. But in the first and second, it is the FL that takes care of everything, they set up pallet racks and make sure it gets into the system 2. It is a little different there.

Then there is a problem with ring handling that you can't really see. In different flows, the first and second which are fully automated, we run on orders and then it is date-based, then you see that now the orders should start and then you click start order and the rings come directly into the cell. But in the third, fourth, fifth, it is manual staging in system 2, and then it is difficult to know which of the

rings has been in the basement. There is a comment field that I don't think is used, but there you could theoretically write when you insert the ring that "this is a pallet from the basement, take this first ". So, one problem is that when a pallet goes into the channel, you remove the HU tag on the pallet, then the connection in system 1 disappears. That is, how long the pallet has been around, etc., it disappears as soon as it enters a channel, so you consume at the product level, not at the pallet level. Then when you take it out of the channel to make returns, you get a new pallet number, but then you take it out of the system 2. Because then an AGV will no longer handle it. So, you take it out of system 2 when you must return it, then you just run it in system 1. So theoretically, a pallet could go to the basement, in system 1, up again, then into the canal, then not be used and go down again. But it always gets a new date because you write a new HU note on it or a new date in system 2 because you put it in system 2 again. It never stays in the same system all the way from the very beginning until it is created again until you have used it. So, it goes in and out of different systems, depending on where it is in the factory. It gets a new date because it gets a new pallet flag. So, then it gets new dates all the time, and then theoretically, a ring could bounce up and down endlessly.

Appendix 6: Meetings log

Participants:

Participant #	Position
Participant 1	**Automation Specialist**
Participant 2	**Manufacturing Reliability Engineer**
Participant 3	**Project Manager**
Participant 4	**Factory Controller**
Participant 5	**Supply Chain Manager**
Participant 6	**Supply Chain Manager**

Meeting 1: Start-up meeting about the basement

Participants: 1, 2 and 3

Duration: Approximately 1 hour

Raised questions:

- How much time does it take to transport redundant components to the basement? And how often?
- How much time does it take to retrieve components from the basement and how often?
- How much does an employee cost?
- What is the average cost of a square meter in the area?

Assignment: Find out what an employee costs and how much time it takes to send/retrieve a pallet for an employee.

Meeting 2: About current structure and holding costs

Participants: 1, 2 and 4

Duration: Approximately 45 minutes

Notes:

- The space is at some places a big mess, discussed and observed during the meeting.
- If the space could be better structured, what should be done with the space in the future?
- If the space becomes more structured, will the factory workers still have tasks to do?

Assignment: Find out what the holding costs are per pallet, and find out if there are any depreciation costs for the redundant components.

Meeting 3: About costs and time utilization

Participants: 1, 2, 3, 5 and 6

Duration: Approximately 1 hour and 15 minutes

Notes:

- From the supply chain participants- the scrap margin could perhaps be controlled and adjusted.
- Some production channels are programmed incorrectly and automatically produce two components if one is demanded -> if everything goes well, one component goes to the basement.
- The controller must approve before something is scrapped.
- Many components that exist in the basement but not in the systems, and vice versa.

Assignment: How much fewer transports need to be made if every pallet under a certain value is scrapped? Based on the last three months, and three value limits on the pallets. How much does each cost, and how much money can be saved if these transports are avoided?