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Aligning Production and Logistics

The case of SKF's E-factory

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Abstract

Efficient production is essential for a production facility to stay profitable in today's high competitive environment. A high resource utility and well organized production flow is also required to meet intra company standards. At SKF's E-factory in Gothenburg, a factory relocation led to frequent changing routines and production flows which hindered efficient and well-coordinated operations. Adapted to the complexity of the factory and the production this work develops a methodology that is designed to enable the mapping, analysis and solution creation for the various problems occurring in the factory. The complexity and interdependency of problems and their solution require comprehensive analysis on the levels task responsibility, equipment utilization, factory layout and information flows. Because the extensive problems cannot be cured with only one solution a tool for prioritization was developed and led to an action plan for recommended solution implementation to improve the operations at SKF's E-factory. The methods developed for this case have high potential to be more generalized and used to solve similar problems.

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List of Abbreviations

APS	–	Advanced Planning and Scheduling
CARB	–	Toroidal roller bearing
EDI	–	Electronic Data Interchange
ERP	–	Enterprise Resource Planning
GPS	–	Global Positioning System
MCSS	–	Manufacturing Control Service System
MTO	–	Make-to-order
MTS	–	Make-to-stock
OEM	–	Original Equipment Manufacturer
RFID	–	Radio Frequency Identification
SLS	–	SKF Logistic Services
SRB	–	Spherical roller bearing
SRTB	–	Spherical roller thrust bearings
WASS	–	Warehouse Application Service System
3PL	–	Third party logistics

1 Introduction

In the first part of this master thesis the background is presented, followed by a problem description, the purpose and the objectives of this thesis. Furthermore, the scope and the limitations as well as the disposition are presented.

1.1 Background

In today's production it becomes more and more important to create an effective production that uses resources in the best possible way. Resources do not exist in an unlimited quantity and because of that it is especially important to treat them economically. Particularly with the increasing attention to topics regarding sustainability companies are even forced legally and by market pressure to reconsider their use of the different kinds of resources. But with increasing complexity of material and information flows which are necessary to perform sophisticated production steps it becomes increasingly difficult to maintain a holistic view over the whole production. The complexity and extent of production facilities makes it necessary to divide responsibility into different functions and departments. In order to manage the integration and cooperation of this wide spread structure, cross functional communication as well as the clear assignment of responsibilities is extremely important.

Through the mapping of the current production processes a more clear view about the various flows can be reached as well as it gives the possibility to identify inefficient processes and improvement potential. In addition, it results in an overview about the boundaries of different responsibilities and areas where integration needs to be improved. Based on the fact that the design of production facilities is mainly based on the optimization of the production process, logistics processes needed to be adapted to predefined designs. This often leads to just the best possible and not an optimal routine for the material movements between the different locations that are part of the production process.

The fact that SKF has to move the whole production from one facility (C-factory including A-heat treatment) to another factory (E-factory) adds further complexity into the material transportation and handling. This is the case because the process of moving all channels takes long time and production needs to be secured during the whole time. Many changes in process and routines occur during this time and make it difficult to reach optimized flows through the whole system. Furthermore, frequent disruptions make it necessary to react very flexible and fast to current situations. This leads to the fact that more resources need to be available in order to enable this flexibility. One of these resources is the handling equipment which is needed to enable the material flows to and from the different channels. For these handlings different forklifts and stackers are used which are often operated by the channels themselves to enable flexible reactions to current material demands. But basically there is the thought that SKF's logistics department shall move all material and the production employees shall only produce. Another barrier to the implementation of an efficient division of responsibilities for material handling is the fact that a new electronically based information system will be implemented that manages material flows. Because everyone knows that there will be a new system it is difficult to establish another initiative for the time before a system is implemented.

1.2 The Problem

Today the E-factory uses a lot of handling equipment like forklifts and stackers for their own processes which cause high leasing costs. The problem becomes even more significant because the utilization for this equipment is quite low. Furthermore, it is not clear organized who is responsible for which tasks where transportation is necessary and no common communication system is established that enables a fast reaction if problems with for example missing material occurs. In addition, the equipment and the factory layout are not adapted to the tasks that have to be performed.

1.3 Purpose

This work is based on the development of a structured method to improve production logistics settings and to solve problems related to this context as in the case of the E-factory at SKF. Revise this methodology with regard to their applicability for similar problems is an additional purpose besides using this methodology to answer the following research question which can be divided into four sub questions:

How can production and logistics be better aligned to each other in SKF's E-factory?

- How can work be divided to utilize competences efficiently?
- How can equipment be used most efficiently?
- How can factory layout support the alignment?
- How should information systems be organized?

Starting with a mapping of the current situation in the E-factory the various problems can be identified on different levels and with different effects. Mapping the factory in this holistic view will even help SKF to be aware of relationships of individual problems. In order to solve this complex problem with many sub problems, one major purpose will be to develop a method to be able to find a structured way to cure SKF's problems. If the method works well within SKF it may even be useful for solving similar problems with this already existing method. Due to the complexity of the problem and the various areas that have to be covered, it cannot be solved with only one superior solution. Rather the objective is to evaluate and prioritize all candidate solutions in order to develop an action plan that proposes the order of implementation of the solutions.

1.4 Limitations

The formulation of this project was open and was based on the optimization of the material flows in E-factory. In order to be able to connect the observations of this case study with good and appropriate academic research and literature it was necessary to draw clear boundaries and narrow the problem down. Therefore this work is limited to cover the internal flows of the E-factory which includes the material flow to and from the factory and within the factory. The E-heat treatment that is connected to the E-factory and supplies it with material will be included as well. Furthermore, the work will mainly cover the material movements to and from the production lines that are handled with forklifts or shelf stackers, without concerning material handling equipment with fix or limited area of usage within the lines. Buffers will be covered in terms of location and area size for the required activities and not in terms of quantities or capital costs.

1.5 Disposition

After having described the background of the thesis, the problem, purpose and limitations in this first chapter, a short overview about the company SKF is presented in chapter 2. From this information together with the theory around this topic a methodology has been developed which guides through the research process and is explained in detail in chapter 4. The related theory is provided in chapter 3 and supports the analysis and solution creation process. To be able to conduct a valuable analysis empirical data was collected based on the methodology considerations and is presented in chapter 5. The analysis in chapter 6 is structured based on the outcomes of the root cause analysis which is conducted in the beginning of the analysis chapter. Combining the outcomes of the analysis, related theory and empirical data enabled the application of the solution creation part in the methodology in chapter 7. Finally, the outcomes of the work are discussed and concluded in chapter 8 and the methodology is critical reviewed after its application. The research process is also displayed in Figure 1.1.

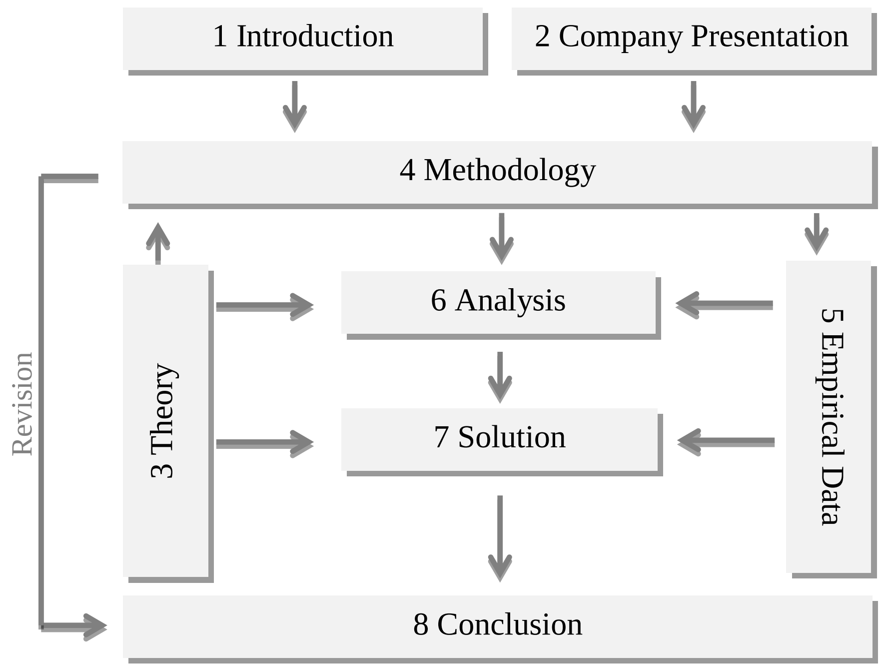


Figure 1.1: Disposition

2 Company Presentation

This chapter describes how the SKF group is organized globally and provides a brief historical background about the history behind its success. Furthermore, the production site in Gothenburg will be presented followed by a more detailed description of each channel in the E-factory and SKF's logistic services (SLS).

2.1 History of SKF

Svenska Kullager Fabriken (SKF) was founded in 1907 in Gothenburg by Sven Wingquist shortly after he had invented the world's first self-adjusting bearing. The company grew rapidly and establishments where made in Europe shortly thereafter. Volvo in fact started as a subsidiary to SKF and in 1926 the first experimental cars were manufactured and a couple of years later Volvo became an independent company from SKF. Through continuous development and acquisitions SKF has become as large as it is today. The company has more than 42 000 employees globally and is represented in more than 130 countries with over more than 100 manufacturing sites.

The SKF group mainly operates through three divisions: Industrial Division, Service Division and Automotive Division. These three divisions serve industrial OEM's, the industrial aftermarket and the car industry. The operation is then divided into approximately 40 different customer segments such as: cars, trucks, wind-power, railroad, paper-industry, etc.

2.2 SKF Gothenburg

The headquarters of SKF are still located in Gothenburg as well as three major factories and one central warehouse, which are all located in the district Gamlestaden (see Figure 2.1). The facilities are named as following:

- "D-factory": medium bearing and roller factory
- "E-factory": large bearing factory
- "RK-factory": roller factory
- "CL": central warehouse

The thesis will be limited to only address the processes that are related to the E-factory (large bearings) and the E-heat treatment facility that is attached to the E-factory.

2.2.1 E-factory and E-Heat-Treatment Facility

The E-factory is part of the industrial division of SKF. The factory produces spherical roller bearing (SRB), toroidal roller bearing (CARB) and spherical roller thrust bearings (SRTB). The factory is to some extent under construction with some channels up and running and some are being set up. A bearing produced in Gothenburg consists usually of four components; outer and inner rings, rollers and cages. In addition, some of the bearing produced also contains guide rings (for some SRB bearings) or sleeves (for some SRTB bearings). The number of cages and roller depends on the type of bearing that is produced and every component can just be used for the specific bearing type it is made for.

Figure 2.1: SKF Gothenburg and E-factory, Source: Google maps (modified)

A SRB bearing (see Figure 2.2) are inherently self-aligning and very robust. The two rows of rollers make the bearings able to carry heavy loads.

Figure 2.2: The Bearing Types SRB, CARB, SRTB, Source: SKF

The CARB bearing (see Figure 2.2) is a relatively new type of radial roller bearing. Its design allows it to combine the self-aligning capability of the spherical roller bearing with the unconstrained axial displacement ability of the cylindrical roller bearing.

In the SRTB bearing (see Figure 2.2) the load is transmitted from one raceway to the other at an angle to the bearing axis. The bearings are therefore suitable to accommodate simultaneous radial and axial loads. Furthermore, the SRTB also encompasses self-aligning capabilities. They do not have two rings like the other bearing types rather they consist of two washers. But for an easier understanding they will also be called rings during this work.

The size of the bearings produced in the E-factory ranges from 600 mm to 2300 mm in outer diameter. The E-factory consists of 6 bearing channels (LT5, LT4, LT3, LT2, CARB, K30) and two roller channels (LR1, CR3) which are described separately in the following. The E-heat treatment which is attached to the factory is also shortly described. The factory layout can be seen in Figure 2.5.

Figure 2.3: Factory layout with channels, Source: SKF (modified)

LT5

The LT5 channel produces SRTB bearing that ranges from 340-640 mm in outer diameter. The channel encompasses approximately 30-50 different bearing types.

LT4

The LT4 channel produces SRTB in the range130-340 mm in outer diameter. The manufacturing process is 95% focused on make-to-stock (MTS) and the remaining 5% is make-to-order (MTO). The channel has about 30 different bearing types in its product range.

LT3

The LT3 channel manufactures SRB, CARB and SRTB bearings with outer diameters in the range 620-1180 mm. Since this channel only manufactures products after a customer order is received (MTO), and since they also produce bearings based on specific customer requirements they have approximately 2000 different bearing types in their current product range.

LT2

The LT2 channel produces SRB bearings, in the range 580-800 mm in outer diameter. The channel is currently under construction in the E-factory and therefore only inner rings will be manufactured in the E-factory until it is completed, hopefully in the end of 2012. The rest of the channel production is therefore situated in the old C-factory. LT2 has currently 28 different bearing types in its product range. Its manufacturing process is 50-60% based on MTS and 40-50% is based on MTO.

CARB

The CARB channel only produces CARB bearings that have a range from 250-600 mm in outer diameter. As of now the channel has 51 different types of bearings in its product range. The channel produces bearings on a make-to-order basis. CARB is limited to only one processing flow in the channel compared to the other channels that can process inner and outer rings simultaneously. Therefore they are limited to only produce either inner or outer rings. This in turn creates a need for buffer space in the close proximity of the channel since the assembly process cannot begin until both inner and outer rings are complete.

K30

The K30 channel produces SRB, SRTB and CARB with sizes that range from 1200-2300 mm in outer diameter. The channel has more than 200 different bearing types in its product range. The channel is currently under construction and will be finished during 2012 and produce twice the number of bearings compared to the current situation.

LR1

The channel LR1 manufactures rollers in various dimensions for the other channels except the CARB channel. LR1 manufactures all their rollers based on the production plan of the other channels. They plan to finish the rollers about three days before they are needed in the other channels. The rollers are transported to the component warehouse until the channels order them from there.

CR3

The CR3 channel mainly produces rollers for CARB bearings and some rollers for SRB bearings. The channel has 70 different roller types in its current product range with sizes up to 65 mm. CR3 only manufactures products on a make-to-order basis from the respective bearing channel, which enables them to minimize their inventory and producing exactly what is needed. It has been decided to move the channel to the RK-factory during the summer 2012 in order to make room for channel K30 which needs the space in order to have an efficient material handling process in the beginning of the channel.

E-heat Treatment Facility

Heat treatment is performed to change the physical and mechanical properties of the steel without changing the bearings original size and shape. This is done by heating up and cooling down the bearing. The main objective of the heat treatment is to strengthen the steel in the bearing in order to increase the service life.

In the E-heat treatment facility only outer and inner rings are hardened. The facility has the capacity to harden all rings for E-factory, rings for one channel in the D-factory, and some rings for the export to other production facilities. Various malfunctions make it in the current situation necessary that the old A-heat treatment is still in use.

The facility is currently under construction with one furnace operating (Heaton 2) and a second one under construction (Heaton 4), which most likely will be finished in the beginning of 2012. Moreover an additional furnace (Heaton 3) is in the planning stage. However, this investment has been postponed until the earliest 2013/2014.

2.2.2 SKF Logistics Services

The main purpose of SKF Logistics Services (SLS) is to provide factories and production channels with raw material, components, spare parts and consumables. In addition, SLS is responsible for almost all forklift transportation within SKF. SLS also manages all inbound material from external suppliers. They have also the responsibility to manage the recycling stations that are located inside in the different factories.

In the E-factory SLS works in a two shift system as seen in Table 2.1 and distribute the components from the component warehouse HF200 and fills the ring buffers for the channels. In comparison, the channels work in a four shift system (see Table 2.2) which results in the fact that the channels do many movements on their own because SLS is not available the whole time.

Table 2.1: SLS current working times in the E-factory

Shift	Time	Weekdays	Number of employees
Daytime	6.48am – 15.30pm	Monday – Friday	2
Extended daytime	13.12pm – 20.00pm 8.00am – 14.00pm	Monday – Friday Saturday	1

Table 2.2: Working hours channels

Shift	Time	Weekday
Daytime	6.00am – 14.00pm	Monday – Friday
Evening	14.00pm – 22.00pm	Monday – Friday
Night	22.00pm – 6.00am	Monday – Friday
Weekend	6.00am – 18.00pm 10.00am – 22.00pm	Saturday Sunday

3 Theory

This chapter will present the underlying academic literature that is used to answer the research question. The theory part is divided into two sections, the production logistics related part and a section that includes methodic tools that are used to solve the problem. The provided theory will be used to motivate proposed improvement in the analysis and solution.

3.1 Production Logistics

Production logistics is defined as planning, developing, coordinating and controlling the manufacturing company's material flows and resource based flows from the standpoint of its production system (Jonsson and Mattsson, 2003). Moreover, the main task of production logistics is to certify that each machine or workstation is being served with the right product or component at the right time in the right quantity. The focus should not be on the transportation process instead it should be to emphasize the optimization and rationalization of the flow through the value adding processes and eliminate non-value adding ones. Since the manufacturing industry is extremely dynamic and a constantly changing process, machines and material handling equipment are being regularly replaced with new, improved ones. This gives the factory and production logistics the possibility to improve the existing system and increase the plant's efficiency enabling them to deliver products according to the demands set by the customers and also enhancing capital efficiency.

This study is limited to consider production logistics inside a factory and therefore is material handling an essential topic which consists of the handling and moving of materials internally in a plant (Jonsson, 2008). Another topic Jonsson (2008) emphasize in connection to production logistics is the production or factory layout which describes how the resources used inside the factory are organized. But production logistics does not only covers material and machines it also includes the staff. Responsibilities for the various tasks have to be defined and considerations have to be made regarding the benefits of organizing logistics as a separate function. The materials management based on well-known principles is in modern manufacturing environments handled by IT systems which become in increasing importance in all areas concerned with production logistics. Based on these considerations literature for this study is reviewed.

3.2 Material Handling

Material Handling is referred to the handling and movement of material from a warehouse facility to and inside a factory (Jonsson and Mattsson, 2008). Immer (1953), states that materials handling is the preparation, placing and positioning of materials to facilitate their movement or storage. Moreover it includes every consideration of the product except the actual processing operation. Another definition of materials handling is provided by Mulcahy (1998), who describes material handling as the basic operation of movement of bulk, packaged and individual goods in a semisolid state by means of a human or a machine and within the limits of a facility. Immer (1953) continues by arguing that from the standpoint of labor, improved methods of material handling offer the greatest prospects for higher wages and better working conditions. Since wages are dependent upon productivity, it is in the interest of the labor to assist management in lowering production cost and increasing output. In addition, a substantial part of heavy lifting, hazard and fatigue from many production jobs has been eliminated. This indicates that an efficient plant is a safe plant and efficient movement of materials is the best way to eliminate injuries to the workers and increase their welfare.

Depending on the distance between the factory and the warehouse, generally there are different employees involved in the steps concerning the transportation process from the warehouse to the production channel. Normally there are specific operators responsible for taking the material out of the warehouse and into a truck, which transports the material to the factory (Jonsson and Mattsson, 2008). The next step in the transportation process is moving the material from the truck to an intermediate storage area inside the factory were all the material for the different production channels is gathered. In the final step of the transportation process, the channel operator or forklift operator collects the required material at the buffer point and then transports it to the channel for further processing.

It is of great concern to stress that both material supply and production are intertwined with each other (Lumsden, 2006). Hence, in order to achieve the optimal solution, these two systems must be developed simultaneously. However, production is usually considered to be the more prioritized of the two. Hence, production and material supply are regularly developed independent of each other (Lumsden, 2006). Booth and Chantrill (1962) state that it is not possible to consider materials handling as a function independent of plant layout, transport and manufacturing process, for it must be integrated with them. Moreover all aspects of production and distribution have become interdependent. Also Phillips (1997) states that equipment, logistics and systems planning must be integrated with manufacturing process, planning and layout planning in order to achieve optimal utilization.

The design of the material handling system depends on how many positions in the facility need some form of material handling. An additional aspect that needs to be considered is how frequent the flows are and how long the distances between pick-up and delivery are (Jonsson and Mattsson, 2008). Aspects that need to be taken into consideration when designing a material handling system are that it cannot be limited to an organizational unit within the company such as logistics, instead the function should be shaped in order to fit the material supply (Lumsden, 2006). Another essential factor that affects the shape and design of a material handling system is the material properties and characteristics. This includes size, shape, weight and material structure. These factors need to be carefully analyzed and evaluated in the construction of a material handling system and selection of equipment (Lumsden, 2006). Factory layout also influences the design of material handling equipment since it sets the boundaries and limitations in which the material handling system has to act in. In addition, plant and machine must be fully employed at the highest possible rate of earning throughout their life (Booth and Chantrill, 1962). Studying materials handling within a factory will increase the resource utilization and make more effective machine capacity for productive profit-earning work available (Booth and Chantrill, 1962).

3.2.1 Selecting Material Handling Equipment

When selecting material handling equipment within a factory there are numerous factors and aspects to take into consideration. It is difficult to find all the decisive factors that affect the choice and shape of the transportation solution in one specific situation (Lumsden, 2006). However, one must bear in mind that material handling adds considerably to the cost of operations but nothing to the value of the product or service. Hence, the best sort of handling is no handling (Booth and Chantrill, 1962).

Characteristics of the product are considered to be the most critical and influential factor that effects the choice of equipment (Lumsden, 2006). The shape or design of the material handling system is therefore dominantly affected by the combined characters of the material (Lumsden, 2006). Booth and Chantrill (1962), states that the first step when selecting material handling equipment is to collect all relevant information regarding the handling situation, which will include details of the following:

- What is to be moved?
- Where it is to be moved?
- Which quantity to be moved?
- Which frequency of movement is required?

When contemplating the implementation of materials handling equipment the aim is to select, on a logical basis, the one which will achieve the lower cost per unit of material handled (Booth and Chantrill, 1962). But the required capacity in metric tons or kilogram cannot be directly compared to the manufacturer’s rating without knowledge of the load size (Lumsden, 2006). When the selection of equipment is dependent on only one product, the features of that specific product are only needed to be obtained. If the selection of equipment is dependent on the properties of several different products then the selection of equipment becomes much more complicated (Lumsden, 2006). Another complex factor is when material characteristics change during the manufacturing process. Hence, the choice of equipment will therefore need to be selected also upon the criteria of the finished product (Lumsden, 2006). An alternative choice of this selection could be to have different types of equipment in specific areas of production.

The transportation frequency of products during one specific time period can also be a decisive factor when choosing equipment (Lumsden, 2006). When analyzing the transportation frequency there are a few questions that need to be taken into consideration such as: non-fluctuating transportation frequency, occurrences of fluctuations in the transportation frequency and possible single occurrences. In an even and leveled flow of material the choice of material equipment can be thoroughly specified with the capacity requirements. Is the flow of transportation frequency highly irregular the choice of equipment will be more problematic (Lumsden, 2006). It is expensive to adjust the equipment to handle the peaks in demand and it will generate low usage of both staff and equipment. Adjusting the amount of equipment according to a mean will generate problems with long delays in production since the equipment and staff will not be able to cope with the peaks in material handling demand (Lumsden, 2006). Therefore, it is quite difficult to select an optimal number of materials handling equipment.

Nevertheless, it is indicated that the use of industrial trucks in various types will give the most efficient handling system regardless of the flow of material in the factory (Booth and Chantrill, 1962). However, the objective and goal when selecting a material handling equipment must be to eliminate all unnecessary movement and handling and reduce it to a minimum of all remaining elements of handling and movement. Therefore, the selected material handling equipment should keep materials moving, even to the extent, wherever possible of processing whilst in motion and to avoid letting material touch the floor (Booth and Chantrill, 1962).

3.2.2 Material Characteristics

Prior to the selection of material handling equipment the nature and condition of the material to be handled must be considered in order to provide the best and most economical material handling equipment for the requirements. The Table 3.1 contains aspects that need to be taken into consideration when selecting material handling equipment.

Table 3.1: Material Characteristics, Source: Ruddell (1961)

Characteristics	Definitions
Material type	The name of the material to be handled, e.g.: steel, food, roller-bearings, coal and so on
Physical condition of material	The material is in solid, liquid or gaseous state
Material shape	Especially important for asymmetrical shapes for which special arrangement needs to be developed for a maximum utilization of available material handling equipment; for non-irregular shapes, length diameter or standard size regular material handling equipment will be adequate
Handling restrictions of material	Specifications regarding special material conditions or characteristics can create limitations on the handling method; Special material can be referred to as radioactive, corrosive, corrodible, flammable, explosive, polished surfaces, vibration sensitive and toxic
Material size range	Minimum and maximum sizes of materials to be handled
Facility limitations	e.g.: Narrow aisles, floor bearing capacity
Material weight range	Minimum and maximum weights expectable for the material; where weight and size are related they can be combined for the material handling equipment selection

The combined characters of the material will put restrictions on available material handling equipment. The most economical equipment should be chosen in terms of widest range of use in order to establish a minimum variety in handling equipment demanded by the overall activities (Ruddell, 1961).

3.2.3 Equipment Classification

There is a wide variety of handling equipment to choose from in order to move, store and package products or components (Ruddell, 1961). In addition, most manufacturers are prepared to modify their products to meet special requirements, or indeed to design special purpose equipment (Booth and Chantrill, 1962). Therefore the need for some sort of classification of equipment within a factory is necessary. Important elements to be considered when selecting a material handling system and specific equipment is the area that the equipment will be used in and the flexibility of the equipment in the specific area (Ruddell, 1961). Therefore, the area of usage will be divided into three different classes: fixed area of usage, limited area of usage and large areas of usage (see Table 3.2). In the fixed area, equipment such as conveyors, automated guided vehicle systems, hoists and scissor tables are included. The second group, limited area of usage, consists mainly of equipment such as large gantry cranes. In the third class, large areas of usage, include equipment such as hand pallet trucks and power driven trucks which is frequent reoccurring equipment (Ruddell, 1961). This theoretical section will be limited to only describe the equipment that is connected to fixed and large areas of usage.

Table 3.2: Equipment Classification, Source: Ruddell (1961)

Classification	Description
Fixed area of usage	conveyors, automated guided vehicle systems, hoists and scissor tables
Limited area of usage	large gantry cranes, traverse
Large area of usage	hand pallet trucks and power driven trucks

3.2.3.1 Fixed Area of Usage

Conveyor System

If the flows within the factory or facility are standardized and non-fluctuating it could be beneficial to use an automated handling system (Jonsson and Mattsson, 2008). Conveyor system (see Figure 3.1) is an example of an automated handling system. It is used to transport material form one point in the facility to another (Jonsson and Mattsson, 2008). Roller conveyors are among the most commonly used forms of line restricted internal transport and can be used for wide variety number of different goods (Lindkvist, 1985). There are two different conveyor systems, one where the material is automatically transported by power driven rollers and the other one uses gravitational force, indicating that the material is moving since the conveyor is leaning to a certain degree or that it demands manual force to move the material (Jonsson and Mattsson, 2008). There are also combinations of gravity conveyors and power driven conveyors, these combination conveyors are for example used for storage of material before assembly. There is an extensive amount of different types of conveyor systems such as; floor based roller conveyors, chain conveyors and roof mounted hanging conveyors (Jonsson and Mattsson, 2008).

Figure 3.1: Roller Conveyor, Source: www.asconveyorsystems.co.uk

The characteristics of the material being handled will impose limitations on the conveyor system used. Roller conveyor does not provide continuous support like a belt does. This creates restrictions in terms of applicability since the materials surface needs to be more or less even (Jonsson and Mattsson, 2008). Hence, the need for unit load standards such as a pallets or container is required when using a roller conveyer system in order to prevent material from being wedged between rollers (Jonsson and Mattsson, 2008). As a rule the distances between the rollers must be adapted to the smallest item carried and that the goods should be in contact with at least three rollers simultaneously (Lindkvist, 1985). In addition, to the use of standard unit loads the angle of the incline of the conveyor can also help to prevent material from getting wedged between rollers (Jonsson and Mattsson, 2008). Some of the greatest scale economies arising from the use of materials handling equipment are achieved through the use of appropriate equipment and the ability to integrate the use of one type of equipment with another, for example, forklifts trucks can be made to feed conveyers and to remove goods from them (Booth and Chantrill, 1962). Hoists are also an alternative equipment to use in a fixed area. The hoist is used for lifting equipment vertically and is positioned in the near proximity to the work stations (Ruddell, 1961).

Scissor Table

The scissor table (see Figure 3.2) is regarded as a versatile and ergonomically efficient material handling equipment for working stations within for example the manufacturing industry. The table provides features such as, tilting and lifting the pallets or unit loads in order to make it easier for the operators to reach the material. In addition, the scissor table can also be made movable; this enables the equipment to be very flexible and can therefore be adjusted to different situations within the working station. When selecting a certain type of scissor table considerations needs to made in terms of product characteristics such as, how large are the products that will be lifted and what it is the total weight of the product. Furthermore, considerations regarding how the product will be placed on the scissor table are also important. This is since for example the manual pallet jack requires the table to be in level with the floor. But if using a low-lifter or other types of powered material handling equipment the table does not need to be lowered into the floor. The variations are substantial and it is important to choose the right equipment in order to establish an ergonomic and effective working station.

Figure 3.2: Scissor Table, Source: www.prestigeconveyors.co.uk

3.2.3.2 Large Areas of Usage

When heavier lifting, further distances and quicker transportation are required in order to transfer material the use of power driven trucks is required. The power driven truck exists in wide variety of designs with numerous different features depending on manufacturer. The initial cost of this equipment is not excessive though operating costs are relatively high (Booth and Chantrill, 1962). The capacity of each piece of equipment can be specified and consideration of this in relation to the work load will accurately indicate the number of machines required (Booth and Chantrill, 1962). Another aspect to take into consideration is that this type of material handling equipment requires aisles for operation and therefore tends to make greater demands on space allocations. However, the stacking features more than compensate for this by their ability to use available “air rights” (Booth and Chantrill, 1962).

The fork-type power driven truck is probably the most frequently reoccurring material handling equipment within factories and warehouse operations, its ability to adapt and adjust to many different situations makes it an extremely versatile equipment.

All fork-type power driven trucks can be provided with fork extensions. This feature makes the truck flexible and enables it to be used in several situations. As an example, the fork extensions are practical when there is limited space inside the production channels and need for half-pallets is the most frequently reoccurring unit load and the use of EUR-pallet are seldom (Ruddell, 1961). Therefore the fork extensions provide the ability for the stacker to lift EUR-pallets when the situation requires it. However, considerations need to be made regarding the reduced lifting capacity when the extensions are used. Therefore, the operators must have adequate training in the handling procedure in order to prevent any accidents from occurring. Table 3.3 shows an overview of the various types of material handling equipment which can have a large area of usage relevant for SKF’s E-factory. They can be grouped into four major groups which are explained in the following sections.

Table 3.3: Large area of usage handling equipment, Source: www. atlet.com

Type of Equipment	Lifting capacity, Max [metric ton]	Height capacity, Max [mm]	Suitable area of distance	Maneuverability	Indoor or outdoor use
Pedestrian pallet truck	1.3-3.0	120-130	short	high	Indoor
Platform pallet truck	1-2	130-165	short	high	Indoor
Rider pallet truck	2-3	120	long	medium	Indoor /outdoor
Pedestrian stacker	1.0-1.6	3500-5400	short	Medium	Indoor
Platform stacker	1.5	4628	short	medium	Indoor
Rider stacker	1.25-1.5	3640	long	medium	Indoor
Counter – balanced truck	1-5.5	5550-6000	long	High/medium	Indoor /outdoor
Hand pallet truck	2.5	190	short	high	Indoor

Hand Pallet Truck

The hand pallet truck (see Figure 3.3) is a non-power driven handling equipment that can be used in large areas instead of a power driven forklift. The benefits of the hand pallet truck are that they are particularly adapted for the use in narrow aisles when there is a shortage of space (Mulcahy, 1999). Most industry professionals recognize that the hand pallet truck is the most basic non-powered material handling equipment. Their lightweight enables them to operate in areas where larger powered lifts cannot enter due to the limitation of the floor load bearing. Due to the narrow turning radius, maneuverability, simple operation and low maintenance is the hand pallet truck used in any warehouse or plant function to move a pallet load over a short distance (Mulcahy, 1999). They are relatively inexpensive and can therefore be made available to many areas for discontinuous or standby use (Ruddell, 1961). The hand pallet truck is perfect for feeding or supplementing powered equipment and short transportations between production machines and main aisles to permit more efficient use of heavier equipment within the main aisle (Ruddell, 1961). Mulcahy (1999), states that there are several disadvantages with a hand pallet jack such as that it requires manual or employee power, it is difficult to use for pallet transport over a decline or incline travel path and it is difficult to transport pallets over long distance. Lindkvist (1985) claims that since a hand pallet is heavy to move it should not be used for distances over 30 meters or for more than 30-40 pallet movements a day and that the weight pulled on a hand pallet jack should not exceed, 200-300kg. As a rule of thumb switching to a powered truck is required when 500kg of materials has to be moved 20 meters 35 times a day (Lindkvist, 1985).

Figure 3.3: Hand Pallet Truck, Source: www.directindustry.com

Stacker

The stacker trucks (see Figure 3.4) can also be referred to as high-lift fork trucks. The stacker model exists in walking, riding or sitting model. The walking and riding models also use a control handle to operate the truck with. Stackers are more compact than forklift trucks and can operate in narrower aisles (Lindkvist, 1985). The stacker is therefore primarily used in areas where there is a limited amount of space. In order to prevent the load from over balancing, the truck the need for a large and rather unpractical body structure is required. However, a way to solve this problem when lifting goods in high positions is the use of straddle outriggers. These outriggers have the appearance of forklike extensions and are designed to prevent the truck from overbalancing (Ruddell, 1961). The outriggers are usually consisting of 75% of the fork length and are equipped with small wheels that are in contact with the floor surface.

Figure 3.4: Stacker, Source: www.directindustry.com

The disadvantages regarding the stackers are that they require smooth surfaces to operate on due to the outriggers (Ruddell, 1961). Lindkvist (1999), states that stacker trucks are used where there is a need for low to medium volume moving and stacking of pallet loads and where the floor surface is satisfactory. In addition, the outriggers require space underneath the pallets. The lack of space requires extensions to retract the load which in turn demands wider aisles for the truck to operate and maneuver in (Ruddell, 1961).

Counter Balanced Truck

The counter balanced truck (called forklift truck in the continuation) is the most common truck type and can be used for handling most forms of materials (Lindkvist, 1985). Between 40 to 50 % of trucks sold in Sweden are forklift trucks and have either three or four wheels (Lindkvist, 1985). In warehouses or plants the forklift truck (see Figure 3.5) is one of the most commonly or frequently used vehicles (Mulcahy, 1999). According to Mulcahy (1999), this is due to the fact that forklift trucks are manually controlled mobile aisle, maneuverable, versatile and flexible.

Figure 3.5: Counter Balanced Truck, Source: www.usedforklifts.com

The difference between a forklift truck and a stacker is that it can lift additional weight and access superior lifting heights. Forklift trucks are regularly chosen when there is a general purpose work and there is a need to manage different types of materials (Lindkvist, 1985). Mulcahy (1999), states that the forklift truck can easily handle business volume fluctuations and is easy to relocate. However, the forklift truck is not suitable in confined spaces (Lindkvist, 1985). The electric forklift trucks provide zero emissions and can therefore be used in interior areas or other facilities where else personnel would be harmed by emission fumes. The truck comes in a wide variety of models with different features that enables the operator to adjust the equipment for his or hers specific needs. Special considerations must be made regarding the forklift travel path layout in terms of the overall width of the forklift truck and a safety factor or clearance which determines the in-house forklift truck travel path width and building passageway width (Mulcahy, 1999).

Since the power of the truck comes from a storage battery mounted on the truck, the battery needs to be recharged at intervals depending on battery capacity and frequency of use (Ruddell, 1961). An additional aspect that needs to be taken into consideration is the provision of battery charging equipment. Laws and regulation stipulate the shape and specific requirements concerning the demands on the charging area. Furthermore, when the frequency of use is high and the management demands as few trucks as possible, a reserve battery replacement is useful. This eliminates the need for the truck to charge eight hours after an eight hour shift of frequent usage, instead the operator simply switches battery and the truck is fully operational.

Pallet Truck

The pallet truck (see Figure 3.6) is somewhat similar to the manual pallet jack with the addition of a power package. The truck provides high maneuverability and can be used in most occurring areas which are available to a manual pallet jack (Ruddell, 1961). The pallet truck is the simplest and cheapest powered vehicles for handling pallets and stillages. They are designed to transport material over a distance of approximately 50 meters, on hard smooth surfaces (Lindkvist, 1985). If there is a platform available, longer distances are possible. The truck enables the movement of normal walking speed, when pallet jacks only provides the movement of 50 to 60 % of normal walking speed due to the effort of overcoming the friction and resistance. The maneuver controls are located on the handle bar which enables single hand control (Ruddell, 1961). When using a pedestrian or platform truck the operator walks or rides behind the powered pallet truck (Mulcahy, 1999).

Figure 3.6: Pallet Truck, Source: www.atlet.com

3.2.3.3 Kentrucks

In terms of material handling equipment in the E-factory there is frequently reoccurring equipment that is termed Kentruck, which needs special consideration when evaluating and analyzing the handling equipment in the E-factory. The Kentruck is a hybrid between a normal hand pallet truck and a stacker which is used for several different movements inside the channels from acting as scissor table in assembly to transporting and moving rings and components between processing and assembly. The Kentrucks have a maximum loading capacity of 800 kg and are currently in a general poor shape due to the fact that the company that manufactures them has ceased to exist, which eliminates the possibility to replace them with new similar trucks. Hence, they need to be repaired often and elaborately in order to function properly.

Furthermore, the Kentrucks need to be replaced in the near future in order to prevent any malfunctions caused by a complete breakdown and because they are not allowed to function as a "static" scissor table according to the production channel managers, due to the fact that they are not designed for this purpose. This creates another incentive and motivation why the Kentrucks should be replaced with other handling equipment for example scissor tables. The fact that the scissor tables can be made movable like the Kentrucks will eliminate any problematic conditions for the channel operators in terms of static area of usage since the operators might want to have the possibility to adjust the scissor tables pending on the current components that is going to be assembled. In addition, when choosing a scissor table considerations need again to be made regarding product characteristics in terms of the largest and heaviest component or load unit that is going to be lifted by the scissor table and how "moveable" the tables are desired to be. Regarding the lifting features of the Kentrucks the scissor tables can provides an equal feature in terms of lifting the components in a medium waist height.

As an alternative to the Kentruck also the hand pallet truck can be used instead of a power driven truck, which in this case is the Kentruck. In order to keep the same versatility as the Kentruck a hand pallet truck could be used as a complement to a scissor table. Research was also done regarding the existence of similar equipment that resembles the outdated Kentrucks. It was found that there are several handling equipment suppliers that provide such equipment. Therefore, when replacing the Kentruck considerations must be made on whether or not a scissor table or similar equipment will provide sufficient features for the channel operators.

3.3 Factory layout

The theory behind factory layout describes the most efficient way to organize and combine employees, material and equipment within a factory. Booth and Chantrill (1962) states that the layout of a factory should be made to provide the best working relationship between space and labor. In order to achieve the optimum relationship between these elements an analysis of movement and handling is required. Greasly (2007) claims that factory layout design is concerned with the physical state of resources such as equipment and storage facilities. Moreover, the layout is designed to facilitate the efficient flow of materials through the manufacturing system. The main functions of efficient factory layout can be used for either manufacturing, office or storage areas (Ruddell, 1961). The factory can be considered as an entity consisting of people and machines which core purpose is to produce products. The benefits of an efficient factory layout are numerous, touching all elements of operation when properly installed such as: decreasing production cost, enhancing productivity, strengthens employee morale and also makes it easier for management to perform their duties (Ruddell, 1961).

Another aspect of the factory layout is that it can have an important effect on cost and efficiency of the operation and can entail substantial investment in time and money (Greasly, 2007). But in several operations the installation of a new layout or altering of an already existing one can be problematic to change once implemented due to the substantial investment demanded on equipment, loading docks, gantry cranes etc. (Greasly, 2007). In order to reach the goal of an efficient factory several considerations need to be taken. Since handling of material is not value adding to the product it only provides place utility. Therefore material handling must be held to minimum cost and not cause any inconvenience to manufacturing instead it should act as a compliment to the production process (Ruddell, 1961).

Improving material handling can be one of the advantages of an efficient factory layout since the factory layout enables the equipment to be better localized (Ruddell, 1961). The reduction of handling distances are also established as well as an enhanced coordination of the complete handling of material. The use of a standardization system when choosing equipment reduces the number of available equipment and will therefore increase flexibility without decreasing efficiency (Ruddell, 1961). An efficient factory layout enables an effective use of the available area. When building a new factory or making substantial alternation in an existing one it is extremely important to plan and coordinate equipment and other services as much as possible in order to make them compatible. This is necessary since they need to coexist without conflicts (Ruddell, 1961). Changing layout may have an effect on any or all of the activities within the factory and therefore it is imperative that a study of materials handling is performed (Booth and Chantrill, 1962). Phillips (1997), states that the best-designed plant layout cannot overcome a poor choice of materials handling equipment. Many practitioners believe that the selected materials handling process coupled with proper space allocations is key to the plant layout process. Hence, one cannot separate materials handling analysis from the plant layout.

3.3.1 Aisles

An important aspect of factory layout is the aisle width required for stacking and the required width of intersecting aisles. First, considerations need to be made regarding the aisle when stacking at 90° angles to the aisle since this require the greatest possible width. Aisle width is therefore dependent upon truck dimensions, load dimensions and desired clearance (Ruddell, 1961). Mulcahy (1999), states that the optimum aisle width can be achieved by using the minimum aisle width recommended by the supplier or manufacturer of the material handling equipment. Another important aspect to take into consideration in terms of designing aisles is to decide whether or not it should provide movement of both personnel and equipment and if it should provide one or two way traffic (Ruddell, 1961). Therefore it is important after having decided traffic pattern of the aisles to ensure and prevent any hazardous conditions for personnel involved. To assure safety, personnel aisles should be designated and kept separate from aisles used for the movement of materials with handling equipment (Ruddell, 1961).

Separate widths can be determined for each aisles type based upon specific traffic pattern of that aisle. Main aisles are therefore usually wider than so called branch aisles due to lower traffic demands (Water, 1996). The aisles should as much as possible be straight and normally intersecting at right angles with sufficient clearance to permit good view of intersecting aisles traffic. If the view of intersecting aisles is in some way restricted supplementary devices such as mirrors or signals should be used (Ruddell, 1961).

3.3.2 Floor bearing

Structural building limitation in terms of floor limitations is also an issue to take into consideration when planning an effective factory layout (Ruddell, 1961). This aspect is extremely important to take into consideration when multiple-story buildings are being considered since it might be possible to create an overload on the structural limit of the floor. The use of heavy equipment must be cautiously planned so that the floor is able to support the load (Phillips, 1997). In addition, consideration must be made regarding the fact that when wheeled equipment is used the weight of the equipment plus its load is concentrated on the small area of the bearing surface of the wheels, and the stress on the floor is greater with a concentrated load than with an evenly distributed one (Chantrill and Booth, 1962). Changes in structural support of the building should only take place in certain part of the factory and not throughout the entire structure (Phillips, 1997). Moreover, it is also important that the floor is constructed to meet the stress involved plus a safety factor, to make adequate provision for possible future developments in plant handling equipment which might increase in weight (Chantrill and Booth, 1962).

3.3.3 Work station

The very foundation of any workstation starts from planning the individual work station. In order to create sufficient workstation aspects such as buffers for incoming material, storage of finished parts and area for handling facilities needs to be carefully planned (Hill, 2001). Space for incoming material must be planned according to the maximum reasonable incoming material that can be expected at the work station during any production period. This should be based upon the method of handling, rate of production and production schedule (Waters, 1996). According to Jonsson and Mattsson (2008) in most cases the production channels have limited buffer space to store material. The storage of finished goods must also be carefully planned. There must be sufficient space for storage of maximum probable finished materials that can be expected to be in temporary storage at the work station (Ruddell, 1961).

In addition, to providing storage for incoming material and finished products there must be sufficient space allocated to the requirements of the material handling method (Waters, 1996). This should include easy access for factory logistics in terms of delivering unprocessed material to collecting finished products and delivering them to external buffer zones. When planning this process considerations must be given to moving material to and from the working station with as little interference as possible to the channel operators (Waters, 1996). In order to establish this, provision must be made in order to create reasonably safe clearance for operator’s movement within the station. Therefore it is common to create a buffer zone for the operators which they can collect material from and move to the immediate machine area or assembly. In addition, the operator may be required to move finished products from the immediate area of the machine to the product channel buffer zone for finished goods from which factory logistics can collect the products.

3.3.4 Morale

Finally an efficient factory layout will strengthen the morale of the workforce since it provides convenience and comfort. Factors that affect this aspect can be anything from sufficient heat and ventilation to having sufficient amount of material in order to produce the required products to not having to go outside the factory and collect parts from an external storage facility since the buffer zones in the channels are too small in order to cope with demand and the factory logistics function does not have the capacity or manpower to serve the factory's needs twenty-four-seven.

3.4 Logistics as a Separate Function

Based on the notion of the focusing on core competencies, logistics is one of the most common functions to be separated from the normal production process. This can be done on the one hand by creating an independent division inside the company or on the other hand the logistics service can be outsourced to another company a so called third party logistics provider (3PL). But no matter which kind will be used the motives, challenges and risks are quite similar. In addition, the implementation and change process need to be considered carefully.

3.4.1 Motives

The advantages of using 3PL are extensively covered in literature and the factor of focusing on core competencies (Pruth, 2002; Coyle et al., 2011) is always included and reflects one of the major reasons for outsourcing logistics or other activities. But Pruth (2002) even found more very reasonable factors that support an outsourcing strategy. One is the improvement of the logistics function in order to be more competitive. When products become more and more similar to that of competitors other ways to compete and to find competitive advantages like superior logistics services are necessary. Another advantage is the shift from logistics cost as fixed cost of the production to variable costs which will lead to more flexibility to react on market changes as well as a shared risk regarding the used resources in the processes (Ahl and Johansson, 2002). Furthermore, seasonal and other variations can be handled better because of the increased flexibility. Probably the most important reason for every company is the high cost reduction potential especially in the long run. Some specific advantages gained from a logistics partnership are economics for scale and scope, more efficient operations, decreased labor costs, reduced investments as well as faster and greater change. In addition, provision of knowledge, more efficient operations and an increased range of services are positive consequences of 3PL collaboration. Even the control of cost and service performance is improved when logistics is separated from the core operations (Pruth, 2002).

3.4.2 Risks and Challenges

One of the most significant risks that arise from the cooperation with a 3PL provider is the dependency on this one firm and the reduced control over logistics activities (Pruth, 2002). Therefore, companies may not perceive synergies from single-sourcing logistics and rather spread the risks among many logistics service providers to make everyone easy to replace. But this harms of course the efficiency of the logistics services (Coyle et al., 2011). Another problem is the complexity of the intern flows that will make the communication and integration of a 3PL service quite difficult. This factor even includes the resistance of the own employees towards 3PL service because they may see a threat to job security or do not believe in improved performance. But it is very important to have the support of the own employees for a successful partnership. Furthermore, from a short term perspective cost for the 3PL integration may even increase and make it difficult to justify a change because also the service quality possibly first decrease before improvements are notable. One challenge that persists after the change to 3PL is the necessity to maintain a certain level of expertise in the field to be able to communicate expectations and to handle appropriate measurement systems (Ahl and Johansson, 2002).

3.4.3 Logistics Change Process

Even if the best solution is found for the existing operations it is necessary to implement this as well. To carry out a successful change process is everything else than easy. Especially logistics has influence on many people with different functions that have to change their daily work routines. People are often not willing to change and do not see the reasons for change. Therefore it is at least as important to have a good strategy to implement changes as to have the right logistics solution (Aronsson et al., 2003).

In logistics literature the area of change and implementation of change is seldom covered explicitly. Therefore, it is necessary to apply the general change theory adapted to logistics problems. Carlsson (2000) identifies three different models of change, linear, processual, and circular, that can be used dependent on the extent of change (see Figure 3.7).

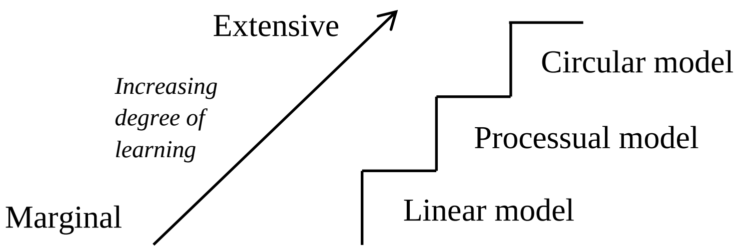


Figure 3.7: Link change models and extent of change, Source: Carlsson, 2000

Linear Model

For the linear model change is considered as solution-oriented and consists of two main phases, formulation and implementation which are clearly separated and view change as a decision making process (see Figure 3.8). The implementation process is seen as an unproblematic exercise based on directives (Carlsson, 2000). The linear model is dominating in logistics literature but will not always be the best option based on the extent of the change (Lindskog, 2003).

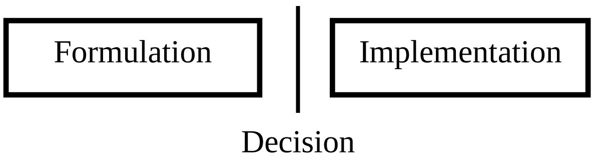


Figure 3.8: Linear model of change, Source: Carlsson, 2000

Processual Model

The processual model, according to Carlsson (2000), regards change as the social process among affected actors that takes influence on the whole process. In this model the organizational formation is much more important than the formulation or design of the solution. Implementation is no longer seen as unproblematic and awareness that formation can even occur after implementation is included (Lindskog, 2003).

Circular Model

When change is not regarded as separate from everyday life in the organization it can be seen as an applied circular model. The model focus on everyday learning and the organizations have to comply with the evolving environment. A continuous cycle of the activities learning and doing describes this model best.

Each model leads to an approach to logistics change with clear differences. An overview about the approaches is provided in Table 3.4.

Table 3.4: Approaches to logistics change Source: Carlsson, 2000

Approach	Solution-driven	Programmed Process	Learning approach
Model of change	Linear	processual	circular
fundamental logic	Solution produce results	processual results	Conditions are decisive
Change management	Implementation	Formation and implementation	Learning by doing
Focus	Structures	Actors	Structures and actors
Actors	Passive	Engaged	Actively creating
Leadership tools	Directives, instructions	Messages, goals	Dialogue
Key role of leader	Expert	Motor	Constructor

3.5 Logistics and IT

Logistics is very close related to all material flows that need to be performed on the way from raw material to finished product. But when goods move, information is created and need to move as well. There are a lot of things that have to be right in order to provide good logistics service like right place, right goods, right time, right conditions, right documents. Information is critical to be able to fulfill the objectives of logistics and it is important that accurate data is converted into useful information. The quality of information is based of course on getting the right information including to know which information are required and getting access to that information. Furthermore, quality is based on the accuracy of information and efficient communications of the information to everyone who is dependent on getting this information (Bloomberg et al., 2002).

3.5.1 Information Systems

The access to all the information is very important for the operation of production processes and efficient resource use. To collect, organize and share information within logistics, exist different information systems which can be divided into three main categories (Jonsson and Mattsson, 2005). The first category includes different planning and execution systems that consist of databases and programs in order to provide information to support the business process and decision making in the company. Enterprise Resource Planning (ERP) systems usually include system support for all processes of the company and not just for logistics (Jonsson, 2008). They are able to handle and process huge amounts of data that can usually be accessed via internet in real time. Advanced Planning and Scheduling (APS) systems are designed for more specialized application which use ERP data. Based on the underlying operation process performs an APS system calculations that result in finished plans and schedules. In addition, other separate systems are in place to complement ERP and APS systems and can also be more adapted to logistics operations. Examples are a Warehouse Management System which supports storage operations, or a Transport Management System which optimize transportation planning.

The second category includes different kinds of communication systems. The objective of such systems is to communicate and share information between companies or within a company between systems and individuals (Jonsson and Mattsson, 2005). Various communication systems are used parallel to each other in a company and they differ according to their characteristics. For example, information can be exchanged between mobile and stationary units, can be shared spontaneously or routinely, structured or unstructured. Furthermore, there are differences in information amounts and required investments to implement them. The computer based communication of information started with EDI (Electronic Data Interchange) systems which share data in predefined and standardized formats and systems. EDI systems are mainly used for regular and structured information exchange between organizations. Electronic Data Access is used when the company makes some data of their ERP system accessible for their suppliers or customers. Furthermore, all other well-known communication systems like internet, telephone, letters, fax and e-mail are of course frequently used in any organization.

Identification systems account for the third category which enables automatized object identification and data entry into the underlying system (Jonsson, 2008). These systems identify an object, catch the information related to this object and transfer them to a computer system. Except for the faster data input are also the data entry errors reduced compared to a manual data registration. The most common identification system is the use of barcodes and barcode readers. One or two dimensional barcodes can be used based on the amount of information they should content and their security level. Barcodes can also be included in transport and product labels with additionally include written information about the sender and receiver or type of product as well as their amount (Fredholm, 2006). Another identification system is RFID which is expected to significantly increase their number of application over the next years. It uses radio frequencies to identify objects and does not required direct contact between object and reader. Current problems with RFID can be seen in the costs and security issues. In addition, more information can be stored and the identification take place very fast. Furthermore, there are more identification systems available that enable to choose the most proper one according to certain requirements. Examples are magnet stripes like on bank cards, optical identification systems and GPS (Jonsson and Mattsson, 2005).

3.5.2 IT Security

With the emerging of computers and the internet the requirements on protection for secret company information and the loss of data have changed significantly. IT security can be divided into extern and intern security (Fredholm, 2006). The main focus is often on the protection of extern access to information. It is important to assure that all electronic transactions are documented and received by the other one. Furthermore, it is questionable whether e-mails are secure enough to allow sending sensible company information with this medium. But not just external security is important in reality is the intern security just as important as statistics show. Inside the company problems result from employees that are the reason for unauthorized data access. Data may be deleted, distorted or reach the outside of the company. To avoid this kind of problems is it important to clearly define who has access to which data and can do which operations. Furthermore, it is important that everyone is aware of the risks that are related to the use of IT systems and to be sure that legal requirements are fulfilled.

3.6 Problem Analysis and Solution Creation Tools

3.6.1 Root Cause Analysis

To define root cause analysis it is referred to the process which is designed for investigating and categorizing the root cause events with regards to safety, health, environmental, quality, reliability and production impacts (Rooney and Heuvel, 2004). The root cause analysis is one of the most famous problem solving tools and has the objective to identify and determinate the causes of the problems before they reoccur again and again. Okes (2008) emphasize that it is very important to allocate sufficient resources to enable an in depth root cause analysis to avoid frustration by the employees because of reoccurring problems. He also mention that root cause analysis is a cognitive process that makes it necessary to be aware of cognitive biases and therefore need sufficient guidance and knowledge to be performed suitable.

Root cause analysis is a tool designed to help and identify not only what and how an event happened but mainly why it happened. This is related to the fact that it is only possible for an analyst or investigator to determine the solution for a problem if they want to know why the event occurred (Rooney and Heuvel, 2004). This is then the key to develop accurate propositions to a problem.

3.6.1.1 Definition

There are numerous definitions about what root causes are. Therefore, Rooney and Heuvel (2004) summarize the characteristics of root causes that need to be in mind when doing a root cause analysis as following:

1. Root causes are specific underlying causes

2. Root causes are those that can reasonably be identified
3. Root causes are those management has control to fix
4. Root causes are those for which effective recommendations for preventing recurrences can be generated

There are several approaches to root cause analysis which differ in their underlying reason for conducting the analysis and in their methodology. Even if they overlap, Okes (2009) differentiate between event and casual factor analysis, change analysis, barrier analysis, risk tree analysis and, Kepner-Tregoe Problem solving and decision making. Another advantage with the root cause analysis is the recommended graphical presentation known as the root cause map which shows the causal factors and the identified root causes connected through paths that identify other factors on the way to the root cause identification (Rooney and Heuvel, 2004). Root cause analysis is part of many well-known problem solving models. For example the Define-Measure-Analyze-Improve-Control model used for the Six Sigma process improvement can be used very well to identify root causes through the first three steps (Okes, 2009).

3.6.1.2 The 4-steps Model

Root cause analysis is a stepwise process but in the literature there exist various suggestions about how many steps should be performed. Okes (2008) for example identifies three main components: Problem identification, support data and possible causes. In contrast, Ammerman (1998) describes eight process steps that lead to an action plan based on the identified root causes and several analyses that follow a data collection. In order to increase the understanding of the different steps, this part will exemplarily describe the 4-step model from Rooney and Heuvel (2004) in more detail because it contents all major components. The 4-steps are as following:

1. Data collection
2. Causal factor charting
3. Root cause identification
4. Recommendation generation and implementation

Data Collection

Data is needed in order get complete information and understanding of the problem. In addition, causal factors and root causes related to the problem can be identified. Data collection is the most comprehensive part of the root cause analysis (Rooney and Heuvel, 2004).

Causal Factor Charting

In order to analyze the information which is gathered the investigators provide a causal factor chart that structures the information. In addition, the causal factor charting process identifies gaps and shortages in knowledge as process continues (Rooney and Heuvel, 2004). The causal factor chart is a sequence diagram that describes the events leading up to an incident and also the circumstances influencing the events. In order to include as much information as possible the investigator should begin creating a causal factor chart as soon as possible.

Root Cause Identification

Root cause identification begins after the investigators have identified all causal factors. The Root Cause Map identifies and shows the underlying reasons for each causal factor and enables the investigators to answer questions regarding why a certain causal factor exists (Rooney and Heuvel, 2004).

Recommendation Generation and Implementation

The final step is the creation of recommendations. After having identified the root causes for a particular causal factor the possibility of creating recommendations that prevent occurrences for reappearing is generated (Rooney and Heuvel, 2004).

3.6.2 Ishikawa Diagram

Another way of identifying and displaying a cause effect relation is the Ishikawa diagram also called fishbone diagram. It can be seen as one type of root cause analysis or a variation of it. When using a fishbone diagram the objective after having established a main problem is to figure out and "boning" out the problem. The focus is on the cause of the problem or the variations and a systematic analysis can therefore be done using a fishbone diagram (Bergman and Klefsjö, 2008).

The Ishikawa diagram has its origin in the quality improvement process and therefore it is required that all different perspectives are included in the analysis. The systematic process starts with describing the different causes regarding the main observed problem and is followed by the second step that seeks to explore and breakdown these causes in more detail (Bergman and Klefsjö, 2008). To make it easier to get started and incorporate more dimensions the so called 7M-diagram as shown in Figure 3.9 can be used. The Ishikawa diagram is a very good tool in a problem solving process and makes it visible when additional data is required to be able to identify the main root causes. Combining the fishbone thinking with the theory of the root cause analysis is very efficient on the way to solve specific problems.

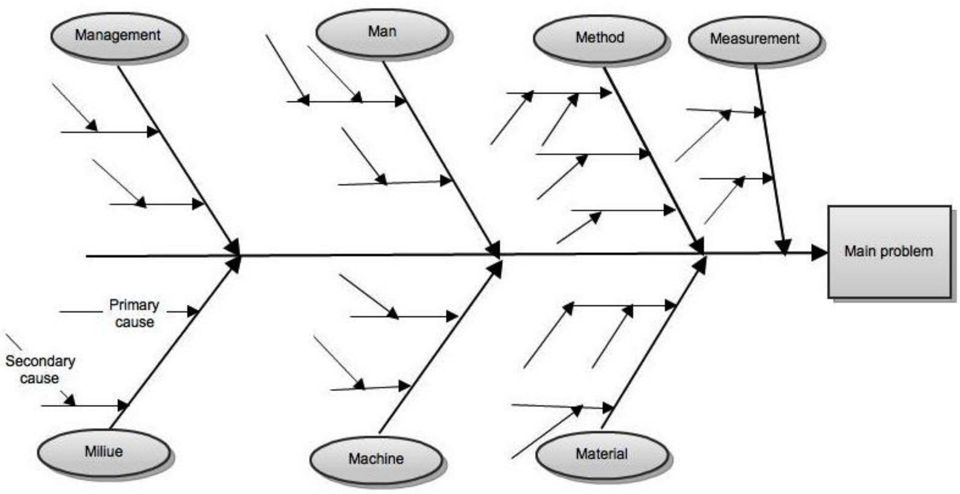


Figure 3.9: 7M-diagram, Source: Bergman and Klefsjö, 2008

3.6.3 Steps of a Solution Creation Process

At the end of an analysis that was conducted because of a specific problem occurred, some kind of solution should be provided. Solutions can be very different because they are adapted to the specific problem they are supposed to solve. There is no “one-fits-all” method available that is suitable in all cases. But there is some literature available that describe steps that can be followed during a solution creation. One example of a solution creation process is provided by Pons and Raine (2005). They include the steps: generate candidate solution, assess solution, select solution and implement solution. This very general process can be adapted to most solution creation cases.

3.7 Theory Overview

The Table 3.5 in this section provides an overview of all described theory and literature topics together with their application in the continuation of this study. Beside their specific relation to an analysis part are the topic related theoretical references used for the solution creation.

Table 3.5: Theory overview

Theory	Application
Material Handling	Equipment analysis
Factory Layout	Environment Fitness analysis
Logistics as a separate Function	Responsibility Analysis
Logistics and IT	Information Flow Analysis
Problem Analysis Tools	Root cause Analysis, Solution Creation

4 Methodology

This part will describe the different steps that led to the solution creation process. It will provide the structure for the empirical data collection and be the basis for the analysis. All the parts are then put together in a framework designed to solve this problem which can also be useful to apply to other problems of this type.

4.1 Research design

This research will be performed in a case study design. This implies the detailed and intensive analysis of a single case that is studied because of its complexity or particular nature (Bryman & Bell, 2011). This case analyzes a single location, the SKF E-factory, and can be seen as a representative or typical case that exemplifies an everyday situation. Case studies in general and also in this case are selected with the opportunity to learn. Together with the qualitative research strategy this leads to an inductive approach of the relationship of theory and research.

The complexity of the analyzed environment makes it crucial to collect comprehensive data about the underlying problems as well as sufficient information about processes inside the organization. The information from interviews with the responsible for the production processes of each channel and other key employees enables to structure the information and base the further analysis on the areas of interest.

Taking epistemological considerations into account the positivism position is followed and methods of natural science are applied. Furthermore, objectivism is the position within ontology that is applied to the nature of social entities, because that will create the most appropriate results from this study. Taking these two considerations together they results in the functionalistic scientific paradigm that creates a good framework to study the underlying operations and will support the problem-solving orientation of this case study (Bryman & Bell, 2011).

4.2 Data Collection

4.2.1 Qualitative Data Collection

Qualitative data includes surveys and interviews and there is a certain amount of facts and information that needs to be gathered and analyzed. It is important that the procedure is well structured and organized in order to achieve the desired results (Bell, 2006). In terms of qualitative data collection structured and unstructured interviews were conducted.

According to Bryman and Bell (2007), structured interviews are conducted in a way that the interviewees are given exactly the same context of questioning. The goal of this style of questioning is to facilitate that interviewees replies can be aggregated. Interviewers are demanded to read out questions exactly and in the same order as they are printed on the schedule. Questions are usually very specific and very often offer the interviewee a fixed range of answers. In an unstructured interview a single question is used that the interviewer asks the respondent. The respondent is allowed to answer freely and the interviewer simply responds to questions being worthy to follow up. The purpose of the unstructured interviews is to gather qualitative data by creating an interview that enables a respondent to discuss and elaborate on a particular topic. The scope of the interview is to grasp the respondent's opinion instead of generalizing about behavior. Open-ended questions will be used in order to conduct the interview. Furthermore, other question will be naturally created and discussed during the interview.

4.2.1.1 Structured Interviews

Structured interviews were conducted with the production managers of each channel. An overview of all interviewees including where and when the interview was conducted is provided within the reference list in the end of this work. Before the interviews were conducted, an interview questionnaire for each production channel and the heat treatment facility was prepared (see Appendix 1). The purpose of these interviews was to get a clear picture regarding the material handling process that affect each channel and also to get feedback from the production managers regarding their opinion on what they could imagine to be improved regarding the processes. All interview where conducted in Swedish and at the interviewee's office to increase the comfort for the interviewee and to get more valuable information. But this made it necessary to translate the answers into English to use them in this thesis. The quality of the information was very depended on the experience of the interviewee and how long they had the job already. The ones that had not been responsible that long for their job became very defensive when they could not answer some of the questions and did not feel that comfortable. Furthermore, it was difficult to find suitable dates with all the people that were to be interviewed and it took about one month until all interviews were conducted.

4.2.1.2 Unstructured Interviews

The unstructured interviews have been conducted with several employees as well as external people that could provide useful information. The first interviews have been conducted with the project managers of the E-factory channels and a consultant who is responsible for the factory layout. The aim of this interview was to get a holistic view on the current situation in the E-factory and to find out what is already decided regarding the future layout of the E-factory. In addition, interviews with employees from SLS regarding problems and their opinion about the current situation were conducted. Through this additional information regarding the problem were received and possible solutions to the problems were discussed.

SKF's main material handling equipment provider was also interviewed to get his personal opinion regarding the equipment which would be most valuable due to his expertise in this specific field. The interview focused on analyzing the current handling equipment in order to understand if the current equipment is the optimal choice for the factory with regards to its current state and the target layout. The interview also focused on how to reduce and replace the current equipment in order to establish an optimal choice of material handling equipment. In addition, valuable insights about different functions and barriers in the usage were gained during the interview.

Throughout the thesis period discussions and interviews with the channels operators have been conducted in order to get their opinion regarding the problem. Furthermore, discussions regarding specific changes in the material handling process have also been made with the operators in order to get feedback from affected employees. In addition, a meeting with the manager responsible for SLS in D-factory was held to get insights on how the processes takes place in another factory in the Gothenburg area. This meeting focused on looking how the D-factory has solved some of the problems that are currently occurring in the E-factory. The information from this meeting was very valuable since it made it possible to see the problems at the E-factory from a different angle and how they might be solved.

4.2.1.3 Observations

In the beginning of the thesis period several hours have been spent in the E-factory just walking around to understand processes and to get familiar with the situation. Special focus was on observing the material handling process to and away from the channels. In addition, the observation also gave the possibility and opportunity to find out the use of specific material handling equipment and to ask additional question to operators when the choice of equipment did not seem to be optimal for the situation.

4.2.2 Quantitative Data Collection

The purpose of quantitative data collection is to find statistical and numerical results in order to localize root causes. The intention of the method is to develop scientific research out of reality. Qualitative and quantitative methods should not be seen as rivals but instead they should be looked upon as supplementary (Bell, 2006).

In terms of quantitative data collection the structured interviews with the production managers were both qualitative and quantitative. This was necessary since it was required to have certain numerical information regarding information about the channels such as: current channel production utilization, setup time, number of products produced in the channel and material handling times.

4.3 Problem Solving Elements

4.3.1 Empirical Data

To understand the way of production in the E-factory including all material flows and routines there was a need to get an overview about these procedures and who performs the different tasks. There was no data available that displayed the tasks and responsibilities for the whole factory. For example managers did not even know how the different tasks are normally performed. Furthermore, it is very useful for SKF to have the current situation described very detailed and to know from where the thesis departs. The fact that some parts of the E-factory are very narrow and other parts are not constructed to carry the heavy weight of the biggest bearings and handling equipment, put constraints on the solution right from the beginning of the thesis. In addition, before starting the analysis in this case it is important to have in mind that the E-factory is not yet finished and that it is already decided on some future changes. Together this makes it necessary to perform an analytical problem description that has four different parts which are described in the following.

Material Flow Chart

First a description of the different material movements to and from the channels is created from the information collected through interviews and observations.

Task Division

Secondly, because the material movements are partly performed by SLS and partly by the production workers and the task division differs from channel to channel, an overview about who is doing what and how is constructed.

Equipment Constraints

The layout of the factory constrains certain handling methods and these limitations are important for the solution creation, therefore it is necessary to describe these constraints.

Future Layout

Finally, the solutions have to fit the fixed parts of the future layout. Decided changes will be described based on their expected implementation and their effect on the current situation.

4.3.2 Analysis Tools

4.3.2.1 Root Cause Mapping

The root cause mapping (see Figure 4.1) will be performed as a combination of the theory about the root cause analysis and the Ishikawa diagram. On the left side the map starts with the obvious problem symptoms and through repeated asking of why these problems occur the root causes will be identified on the right side of the map.

4.3.2.2 Responsibility Analysis

After creating an overview about "who is doing what" this analysis will cover why things are done as they are and what it would require to change the current division of tasks in the material handling. This will be done with the theory background of the advantages of 3PL and why the SLS should take over more tasks.

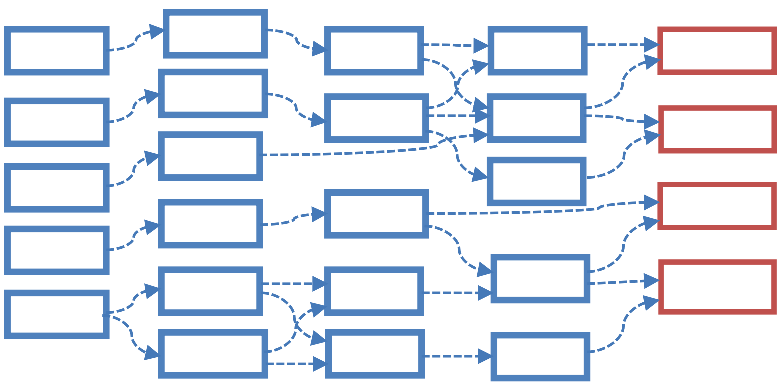


Figure 4.1: Draft Root-cause map

4.3.2.3 Equipment Analysis

With the theory background of material handling in this part the material handling equipment in use will be analyzed based on their usage, their requirements, time in use and alternative equipment.

4.3.2.4 Environment Fitness Analysis
Since the layout in the E-factory is very narrow in some parts and buffer and storage space is limited as well as different constraints are in place, an analysis of the improvement potential of routing, which equipment can do which task, which forks are best to use will be done. This is done with the theory background of factory layout and material handling.

4.3.2.5 Information Flow Analysis
There are several information systems in place today and this has an impact on material flow. Therefore it is analyzed which information are needed for whom and when. In addition, the role the new planning platform WASS will play in the future and which parts it will make easier will be examined.

4.3.3 Solution Creation

Because all the problems cannot be solved with only one single solution, the various solutions will be evaluated and then prioritized to enable to develop an action plan as the recommendation for SKF to solve their problems most efficient.

4.4 Production Logistics Remedy

The previous described steps can be put together to a method that will be a guide through the problem solving process and the outline of the thesis will be based on these steps. The conclusion of this work will give the opportunity to reflect the use of this method and to find out if this method can be used more in general for other problems with the same complexity. Figure 4.2 shows the chart that combines all different steps that are performed on the way to the solution. The fact that this methodology starts with identifying symptoms, continue with finding the causes for the symptoms and ends with curing the “disease” suggest the comparison with a visit at a hospital. Therefore the method is called “Production Logistics Remedy”.

4.5 Validity and Reliability

To ensure the quality of the research it is important to follow the criteria of validity and reliability. To be present in the factory and the observations as well as structured and unstructured interviews over a period of several months gave the possibility to study many different situations and to analyze where the problems actually come from. Identifying all the different sub-problems and gaining a holistic view over the processes made it possible to perform a root-cause analysis to work with the underlying problems and not just their consequences. The frequent feedback that was received and the regular interaction with various actors involved in the processes made it possible to develop improvements that are really beneficial for the whole factory. Several employees with the same occupation were always asked to be able to compare their answers and to reduce personal biases. The weekly meeting with the supervisor at SKF and being located inside the factory during the research period resulted in extensive observations that supported the ideas which were developed in relation to theory.

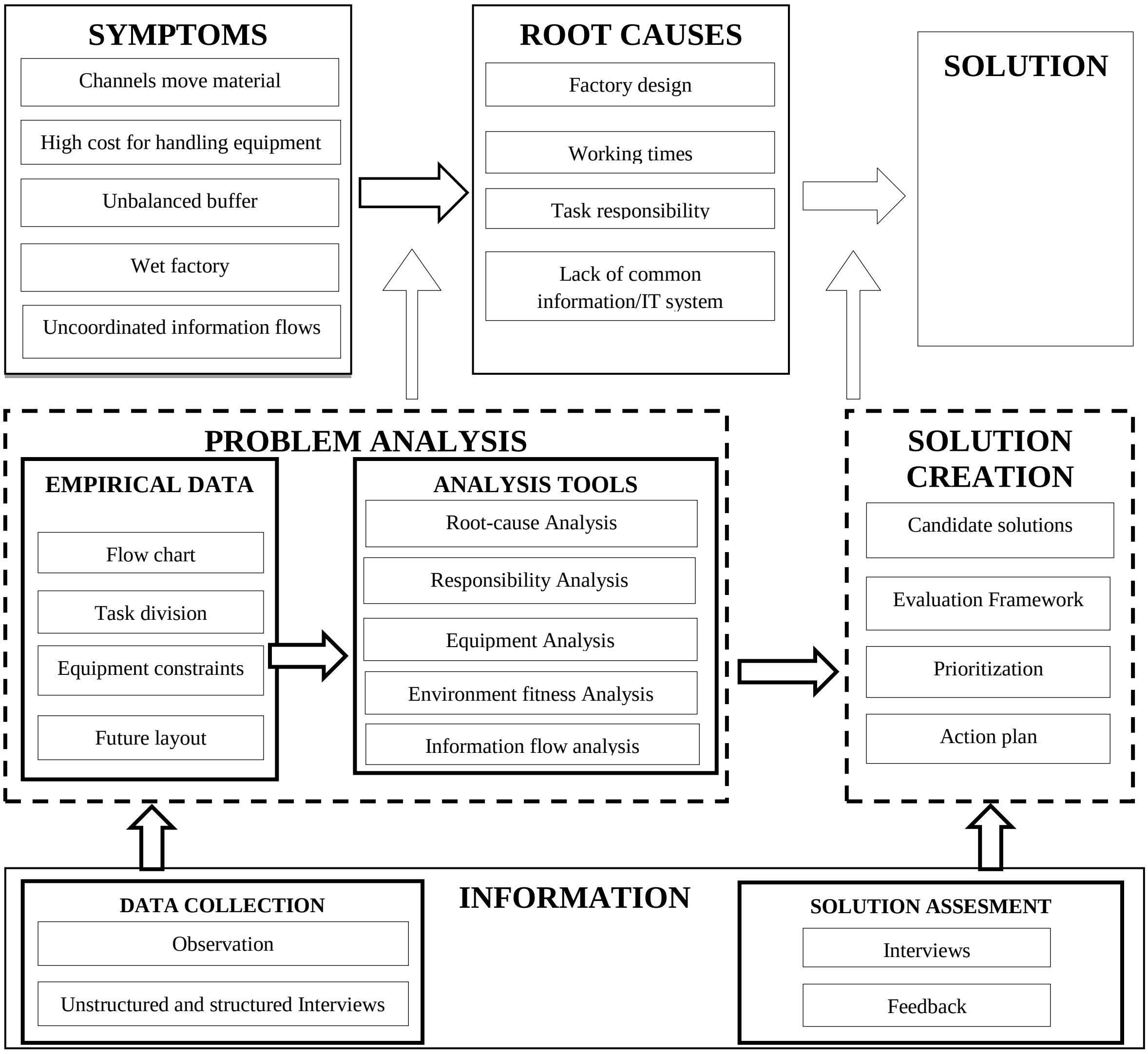


Figure 4.2: Production Logistics Remedy

The advantage of being two people conducting this research has the benefits that observations, thoughts and ideas can always be discussed and compared. In that way focus is remained and further feedback included in the study. The dynamic environment that characterizes the E-factory including the completion process as well as the implementation of already decided changes modify the routines constantly. Therefore an observation at a different point of time would generate other problems and other purposed solutions because of implemented improvements and changing routines. But observing the same routines that were studied in this thesis would show the same problems because the extensive observations and contacts with the factory employees let to clear underlying problems that need to be removed. The best feedback would of course be a successful implementation of the proposed solution and information will be received about the implementation process, which follows this study.

5 Empirical Data

Gathering empirical data and display the current situation as in this chapter was at the same time used to get a clear understanding of the problem. The problem understanding is divided into four sections and problems are identified within these sections. The numbered problems reoccur in the analysis part where they are further investigated.

5.1 Material Flow Chart

To enable the production many different material movements are necessary. All flows are characterized by an intermediate stop that functions as a buffer before and after the production process. Therefore all flows are interrupted on their way to the channel and material movements are increased. On the one hand the basic flows of rings, components and packaging needs to be secured for producing a sellable bearing. But on the other hand the production process causes several additional and special flows. These special flows are for example load carriers and parts that arrived at the assembly but where not used and therefore returned to the component warehouse in order to come back to assembly again when the same bearing type is produced again. Furthermore, the two roller channels have different flow structures because rolls are the major in and output. The different flows and material movements from and to the production channel are displayed in Figure 5.1.

5.1.1 Basic Flows

Rings

To produce a bearing that can be delivered to the customer, an inner and an outer ring is required as well as rollers, cages and packaging material. The so called black rings come from the heath treatment where they are placed on pallets and are moved first to a roller conveyor. The heath treatment is located next to the E-factory in the same building and the roller conveyors are located just behind the gate between these two areas. In the current state all rings for the E-factory except the biggest once shall be harden in the E-heath treatment. But because of frequent malfunctions rings are often harden in the A-heath treatment, another place on the SKF area and are then transported to E-factory by truck and then moved to roller conveyors. The roller conveyors are assigned to a specific channel and a paper with the actual sequence list can be found there. The rings have to be put on the conveyors in the order of the sequence list and that is intended to be done by the employees of the E-heath treatment. In the current situation the E-treatment has not started to harden the rings based on the sequence lists and therefore rings are first placed around the conveyors and that sorted in by the SLS employees. This by hand sorting results occasionally in sorting errors that lead to time intensive resorting.

From the roller conveyors SLS move the pallets with rings to buffer areas next to the channel start. From there the channel move the rings to the first machine where they go through a grinding and turning process before arriving at the assembly. The rings vary significant in size which results in very different amounts of rings on one pallet. Based on the channel rings and finished bearings are on half a EUR-pallet, normal EUR-pallet or even larger load carriers. A problem here is that the central storage can only handle half-pallets in an efficient way and would like to get as much bearings as possible on half-pallets (Problem 1).

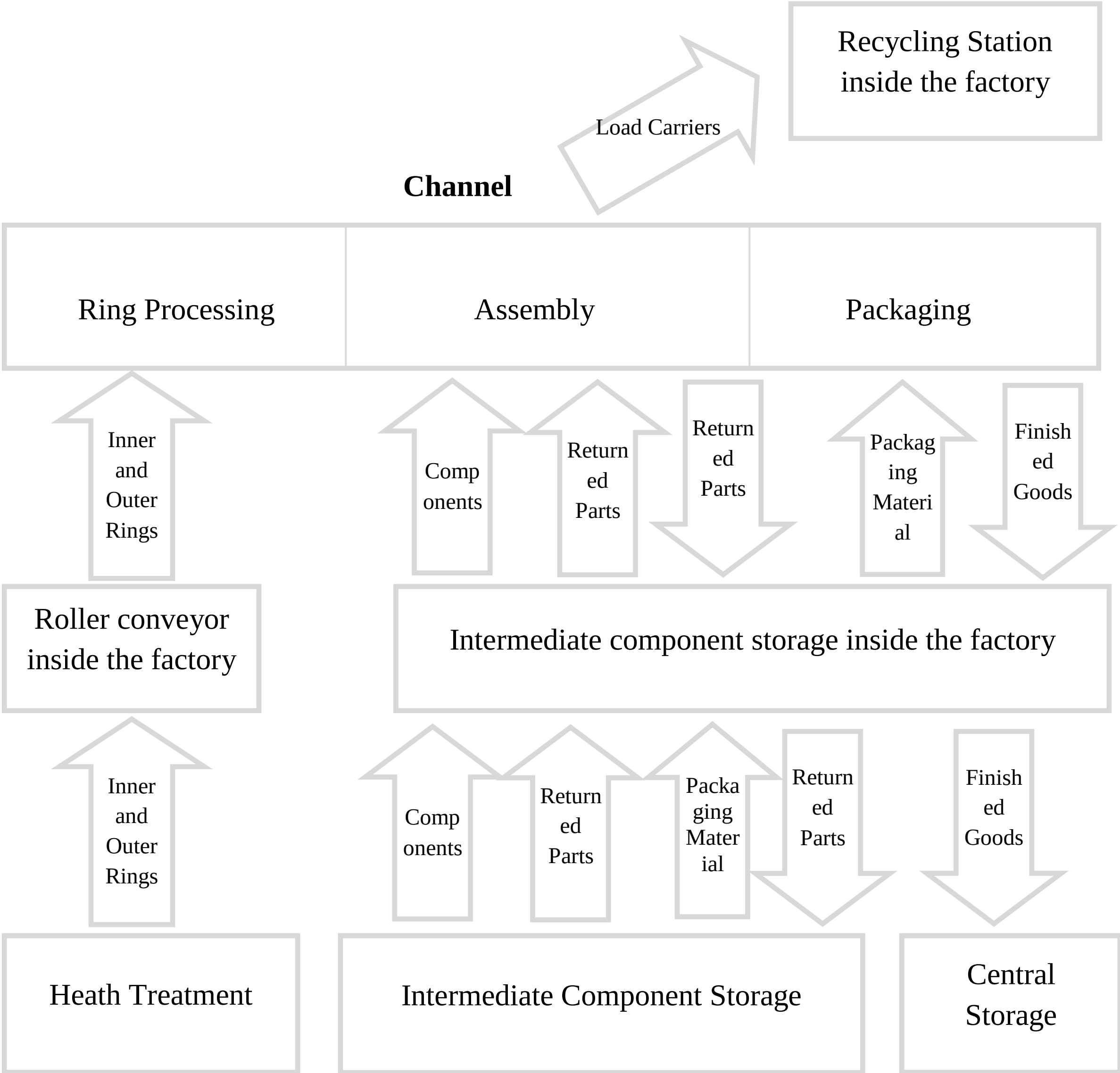


Figure 5.1: Material Flow Chart

Components

The components consisting of rollers and cages as well as guiding rings or sleeves for some bearing types, are ordered from the channel the day before the components are needed. The components are stored in HF200 a building just a few meters away from the E-factory. After arriving at the factory by truck the components are unloaded and moved to a buffer space inside the factory by the SLS forklift drivers. For two channels the buffer space is in the middle of the factory and the channel operators have to go a quite long distance to get them from there (Problem 2). For the other bearing channels the components are placed close to the channel and the assembly area. Components especially cages vary a lot in size and therefore also in the amount placed on one load carrier. The components are going straight to the assembly where they together with the rings are assembled to a bearing.

Packaging

After going through the measuring and preservation the bearing comes to the packaging. Packaging material is ordered like components and arrives at the same places as the components after being unloaded from the truck and moved into the factory by SLS. The channels then get them there and take them to the packaging at the end of the channel. The bearings are either packed in cartons or wooden boxes and then palletized or the box is already that big that they can be handled directly with a forklift.

Finished Bearings

The finished and packed bearings are moved by the channel employees to assigned places from where SLS take them out of the factory and from there are they going by truck to the central storage in the end. These assigned places are located relatively far from the end of the channel and quite long movements are necessary because the pallets have to be handled one by one.

5.1.2 Special Flows

Returned Parts

The described flows for the actual production cause some special flows. The first one is the returned parts flow. Because every bearing needs an inner and an outer ring, one cage and a fixed number of rolls and the parts are produced for one specific type of bearing, the left overs that cannot be assembled to a bearing of the current order, are stored until this type is produced again. There is about one month or more between one type is produced again and therefore left overs are usually returned to the warehouse HF200. Left overs occur mainly because parts are frequently rejected in during the controls before the assembly. To assure that the ordered quantity can be produced are additional rings and components ordered. The parts for return are moved to assigned places by the channel employees and from there moved by SLS to the warehouse. When the type shall be produced again the channel orders the left overs and they go the same way as components directly to the assembly. Rings that have been returned went already through turning and grinding and are ready to assemble when returned.

Load Carriers

When the different parts arrive at the channel they are on some kind of load carrier. These are different types of pallets, pallet tops, pallet covers as well as plastic or paper boxes for rolls. Many of these load carriers are reused by the channel for example for palletizing the finished bearings. Load carriers are even exchanged between different channels and roller boxes are partly returned direct to the roller channels. But to some extent load carriers are not reused (Problem 3) and the standard routine is that they are moved to the recycling station inside the factory when they have reached a certain stack height. This is done by the channel employees. From the recycling station the load carriers are taken to a storage place outside the factory or they are used by other channels inside the factory.

5.1.3 The Roller Channels

The two roller channels in the factory have different inputs and outputs and therefore the material flows differ. The harden rollers are taken by SLS to the channel’s start from where they are entered into the first machine. Channel LR1 has an additional flow because some of the rollers have to be transported to the tumbling outside the E-factory after they went through the first machine. When they come back from the tumbling the operation continues at LR1. This flow is regulated on a visual basis, when there is something to take to the tumbling SLS do that and take back tumbled rollers. Because some rollers have to come again to the tumbling and LR1 wants to have the rollers back as soon as possible they do that on their own sometimes and this makes the flow very irregular and unstructured (Problem 4). The finished rollers are then taken to the so called “intermediate component storage” in the middle of the factory which is used by almost all channels to collect components or place their finished products there. LR1 has to take their finished rollers to the intermediate storage and CR3 rollers are just placed next to the channel be taken to the storage. Another difference is that LR1 handle their rollers that are left over from one type on their own inside the channel and CR3 sends their odd rollers to the roller storage, a building next to the E-factory, from the same place as the finished rollers are picked up. Because CR3 has the advantage to have a buffer area just in front of their channel, they even get all the packaging material to that place. LR1 in contrast has to pick up packaging material from the area in the middle of the factory. The grey metal boxes LR1 gets their input rollers in are picked up from the channel directly and the green metal boxes for the tumbling process are reused in the channel.

5.2 Task Division

The major problem underlying this part is that the channels do a lot of material movement work on their own. This cause high cost for handling equipment related to the channels (Problem 5). The function of SLS is to handle the logistics from and to the channels so than the channels produce and SLS transports. Everyone shall do what he is best at. In the E-factory it differs from channel to channel which material handling is performed by SLS and which is performed by the channel. In addition, the routines and conditions differ in a way that SLS do some handling for one channel but not for the other. In order to be able to improve the situation and increase the tasks in responsibility of SLS an overview of all different material handlings for each channel and who is performing it was created (see Table 5.1). At the same time, it was investigated which kind of handling equipment is used for the movement.

The different material movements from and to the channels are explained in detail in chapter 5.1. The rings are moved from the heath treatment employees to the roller conveyors. Today SLS mainly sort the rings onto the conveyors because the heath treatment does not yet operate based on the same sequence list as the channels. The rings of K30 are in the current situation harden in another heath treatment and transported by SLS to their buffer area next to the roller conveyors. From the roller conveyors SLS move the rings to the channel start except K30 is doing this movement on their own. Every channel has a buffer area next to line start, but because either no roller conveyors are in place in front of the first machine or they are not use them as a buffer (like in CARB) an additional handling is needed to be done by the channel employees to supply the first machine with rings (Problem 6). In the CARB channel the roller conveyors are not large enough to be just filled on daytime by SLS (Problem 7).

The components are taken into the factory by SLS and placed on the intermediate component storage area or they are transported immediately to the buffer areas close to assembly of the certain channel. When they are placed close to the line just a very short movement to assembly is necessary to be done by the channel, otherwise (LT4, LT5) the way to get the components to the channel is quite long. For LR1 the incoming rollers are place by SLS so that just lifting equipment is necessary to start operating.

Table 5.1: Task division and used handling equipment

Material movement	LT5	LT4	LT3	LT2	CARB	K30	LR1	CARB-Rullar
Rings								
Heat threatment -> roller conveyor							-	-
Roller conveyor -> line start							-	-
Line start -> first machine							-	-
Components (Rolls, cages, return parts)								
Component storage -> intermediate storage				-				
Intermediate storage -> assembly				-				
Packageing material								
Component storage -> intermediate storage								
Intermediate storage -> line end								-
Finished products								
Line end -> intermediate storage								
Intermediate storage -> central storage								
Returned parts								
Assembly -> intermediate Storage				-			-	
Intermediate storage -> component storage			-	-		-	-	
returned load carriers								
EUR-pallet					-		-	-
EUR-pallet Cover			-	-	-	-	-	-
Half EUR-pallet				-				
Palett-collars				-				
Pallet cover plate				-				
Rollboxes			-	-		-	-	-
Rackframe	-	-			-	-	-	-
Blue platform	-	-	-	-	-		-	-
Oversize boxes (cages)	-	-	-	-	-		-	-
metal rollboxes	-	-	-	-	-	-		-

SLS	Heat threatment	Channel	Infrequent/reuse	Channel (close by)

Packaging material is taken into the factory by SLS and placed on the joint buffer in the middle of the factory and the channels have to get it on their own from their or SLS places it directly close to the end of the channel. The finished products are all placed by the channel on assigned areas where there are taken by SLS and transported to the central storage. The so called "out-areas" are quite far away from the end of the channels and require many time intensive movements from the channel employees. The buffer area every channel has close to their end of the line are in no case large enough to place the finished products of e.g. one night in order to enable that SLS can collect them directly from the lines (Problem 8). Only in the case of CARB the out-area is very close to the channel.

Returned parts do not occur in all channels, but if, the channels move them to assigned places, close by or more far away, and SLS take them from there to the component warehouse and returns them together with other components. The load carriers are handled very different in each channel and they have their own routines. Many movements occur infrequent and many load carriers are reused within the channel. But in case of too high levels of load carriers within the channel usually the channel operators are responsible to move them to the recycling station from where SLS carries out the further actions. In many cases it is not possible for SLS to take over more tasks because of a lack of routines and assigned buffer or storage areas accessible by a forklift truck that would enable SLS to take components closer to the channel and to collect returned parts and load carriers directly from the channels (Problem 9).

5.3 Equipment Constraints

5.3.1 Accessibility

The layout, the characteristics and the way of working led to certain constraints that force the logistics functions and the equipment to adapt to them and to comply with the limitations. Those constraints arise for different reasons like the factory layout, the product characteristics or the equipment features. The first and maybe most important constraint is the accessibility of the different places inside the factory. The aisles are divided into transportation lanes (main aisles) and lanes for people (branch aisles). Currently the transportation lanes are used by both vehicles and people without any separation (Problem 10). But the aisles that are exclusively used for walking are to narrow or do not meet safety standards for vehicle traffic. This led to the fact that SLS cannot reach all starts or ends of the channels with their forklifts to deliver them with the different parts and therefore the channels use stackers which they drag behind them for those operations (Problem 11).

5.3.2 Turning Spaces

The second constraint is the turning space (Problem 12). This hinders handling on the one hand in the small transportation lanes when refilling buffers and on the other hand when filling or emptying the roller conveyors. The mainly quiet narrow ways in the factory are not designed for high traffic because it is hard to pass each other and no separate walking ways are present yet. The small space that can be used for turning and handling goods led to damages and increase handling time.

5.3.3 Factory Floor

In addition, the factory floor is just in some areas constructed in a way that it can bear the heavy combination of a forklift moving the larges bearings produced. This is important of the channel K30 which produces the largest bearings and therefore are the routs for inflows and outflows of parts and finished goods dependent on the ways with this special factory floor. The size of the parts and goods also limit the movement to certain ways because others are too small to fit through them with this material.

5.3.4 Factory Gates

Another constraint is the design of the gates for the transportation from and to the factory. All parts and goods need to be unloaded and loaded from and to the trucks outside the factory and causes a wet and dirty factory which is not favorable for high quality production (Problem 13). This makes the use of pure inside handling equipment impossible because not even porch roofs are in place at every gate. The nonexistence of docking gates for the trucks makes pure inside transportation very hard to arrange.

5.3.5 High Weights and Fork Length

The very different size of the bearing produced in the E-factory has a significant impact on the requirements on the handling equipment. The high weight of some goods causes that the equipment need to be able to handle the largest weights also if mainly much lighter goods are carried. The same fact is valid for the fork length which needs to be adapted to the size of the pallets carried. Basically all channels handle different pallet sizes and even therefore the required fork length of the handling equipment may not support smooth handling inside the channel. K30 handles even half-pallets and oversize pallets and needs to have equipment available for both kinds of handling. Other channels like LR1 even need different spans between their forks to be able to handle all material. The different requirements complicate the selection of the right handling equipment and adaptation is required (Problem 14).

5.3.6 Stacked Pallets

The last constraint to name here is the fact that pallets used to be stacked on top of each other and therefore lifting equipment is required for handling. This makes the use of pallet trucks inappropriate for most of the operation areas.

5.4 Future Layout

The relocation from the C-factory to the E-factory which already took more than five years is still not completed. The stepwise move of the channels cause even that already moved channels needs to be adapted to new changes. Certain decisions have already been made to come closer to the completion of the relocation and will be implemented in the future. These changes affect the factory layout, channel operations as well as information systems.

5.4.1 Removal CR3

The nearest change with quite significant influence is the removal of the CR3 roller channel from the E-factory in summer 2012. The channel will be moved to the roller factory in the building next to the E-factory. Reason for the relocation is that the space is needed for improved operations and supply of K30 which is located next to CR3.

5.4.2 Roller Conveyors for K30

The removal of CARB3 rollers enables the installation of roller conveyors in the channel K30. These roller conveyors will connect the different machines of K30 and reduce the use of moveable handling equipment significantly. Those roller conveyors can than even be used as a buffer place before and within the channel. This additional equipment shall be in use in the end of 2012.

5.4.3 Removal of Kentrucks as Handling Equipment

On kind of handling equipment frequently used in the E-factory are Kentrucks (see Chapter 3.2.3.3) which can move pallets put also lift them in an ergonomic friendly height. This handling equipment need to be removed or replaced (Problem 15) because on the one hand the company that produced them does not exist anymore and reparations become difficult. On the other hand SKF's security standard does not allow using this kind of equipment anymore.

5.4.4 Completion of LT2

Another channel based change with impact on the factory layout is the extension of channel LT2 until the whole production process is located in the E-factory. Today just inner rings are handled in the E-factory but until 2013 all operations shall be moved so that complete bearings can be produced at one place. This will lead to an increased area used by LT2 and that will affect mainly the current buffer space assigned for components and finished goods. This area will therefore be moved to a more central place with a permanent design, but it is not yet decided about how to structure this area (Problem 16). The future layout as it should look like from today's perspective can be seen the Figure 5.2. In addition, a new measurement laboratory is under construction which will be placed between K30 and the roller conveyors and further reducing the open space in the factory (Problem 17).

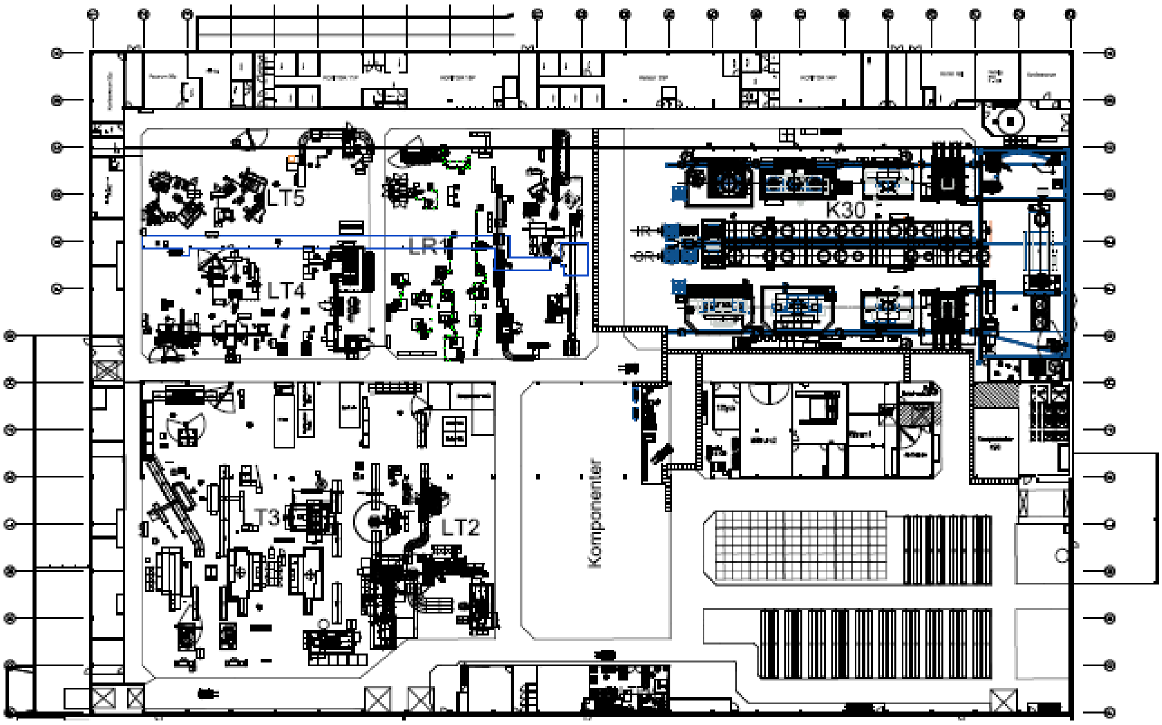


Figure 5.2: Future Layout, Source: SKF

5.4.5 Extension E-heat Treatment

The operation of the so called E-heat treatment effects the necessary movements from and to the factory based on the amount of material that need to come from other heat treatments. The two heath treatment lines in use today do just work with many interruptions and rescheduling is very often necessary. All problems related to that will hopefully be solved in the near future to achieve smoother operations. Furthermore, another heath treatment for the largest rings is supposed to start working in the first half of 2012. Based on capacity occupation one more heath treatment line will be build and a place is reserved for it. When everything is working as planned all rings for the E-factory as well as rings for one line in D-factory and some rings for the export will be harden in the E-heath treatment. The rings that are not assigned for the E-factory did not yet have a place to keep them until they are transported to their destination (Problem 18).

5.4.6 Sequence List for E-heat Treatment

In the field of information systems and flows major changes are planned in the near future. In the current situation the E-heath treatment did not plan and organize their operations based on the same sequence list the channels operate which is provided by the supply chain department (Problem 19). Having the same sequence list would enable the employees of the heat treatment to immediately sort the harden rings onto the roller conveyors in the order they are needed by the channels. To reach a further improvement the roller conveyor lines shall no longer be assigned to one specific channel but instead will a computer based optimization program tell where to place and take rings from.

5.4.7 Implementation of WASS

The whole information system will be changed when the new material flow system WASS is implemented. This system will regulate and control when which part or component is needed and where. To be able to do that WASS communicate with the current warehouse management system MCSS to synchronize stock levels. WASS will work in a way that a demand will be created when a component has been used and the place can be refilled with a new one. To be enable that WASS work in this way buffer places for all parts of the bearing have to organized accordingly (Problem 20). In addition, finished products are entered into the system and the forklift drivers get an order to take them to the central storage. Demand i.e. orders are created either when the robots are enabled to create the necessary information or by manual scanning of the empty or full pallets. In the current situation product labels have many different designs which make a scanning more difficult (Problem 21). The forklift drivers will have a screen inside their vehicles that shows what task they have to do next. This system will reduce the manual work of looking around what is needed, it will smoothen and reduce stock levels and reduce the occurrence of component shortage. The limitations of WASS in contrast are that it is not designed to handle returned parts and load carrier levels and that will therefore still be done manually through visualization. In addition, WASS is not able to prioritize task with shorter time windows and flexible communication between channels and forklift drivers should be possible. The pilot project for WASS started in November 2011 and based on the results WASS will be first introduced in the D-factory and after that maybe in 2013 WASS shall be in place in the E-factory as well.

Table 5.2: Problem Overview

Problem Overview	
P 1: Central storage cannot handle EUR-pallets P 2: Long distance to intermediate component storage P 3: Not reusing load carriers within channel P 4: Irregular production and material needs P 5: High costs because of too much handling equipment P 6: Move each pallet separately into first machine P 7: Limited buffer space in the beginning of the channel, small time window P 8: Limited buffer zones in the end of the channel P 9: No assigned buffer zones for returned parts inside channel P 10: Main aisles not divided in people and vehicle traffic P 11: Aisle between LT5 and LR1 not accessible for a forklift truck	P 12: Limited turning space P 13: Wet and dirty factory P 14: Material handling equipment not adapted to current needs P 15: Removal or replacement of Kentrucks P 16: Unstructured “new” intermediate component storage P 17: Limited space inside the E-factory P 18: Not assigned zones for E-heat treatment buffers (Export and K77) P 19: Not using the same sequence list P 20: Buffers not adapted to WASS or SLS handling P 21: Different product labels

6 Analysis

The analysis starts with a root-cause analysis and each root cause is afterwards analyzed separately. The inputs for the analysis come from theory, empirical data and the methodology. Possible improvements for the various problems are identified throughout the whole part and later used for the solution creation.

6.1 Root Cause Analysis

To find out the underlying causes of the problems and symptoms that are most obvious it is very important to not just fix problems but to solve the causes. As described in the theory chapter 3.6.1 the process starts with the data collection which is also the first step of the problem analysis in the used methodology. The second step is the factor charting and this starts with the symptoms that are on one side reasons for why SKF wanted someone to solve them and on the other side there are the most mentioned and obvious problems that were found through the data collection. Continuing with asking “why” this is the case and mapping the answers let after several repetitions to the identification of four root causes seen on the right side of the root cause map (see Figure 6.1). Having in mind the cause effect thinking from the Ishikawa diagram described in the theory chapter 3.6.2 helps to find the steps in between that led to the root causes. In this case the best visual and meaningful outcome is reached when using a root cause map with a successive flow from the left to the right. The four root causes are now used to continue with the problem analysis and they are analyzed separately to be able to generate recommendations and solutions.

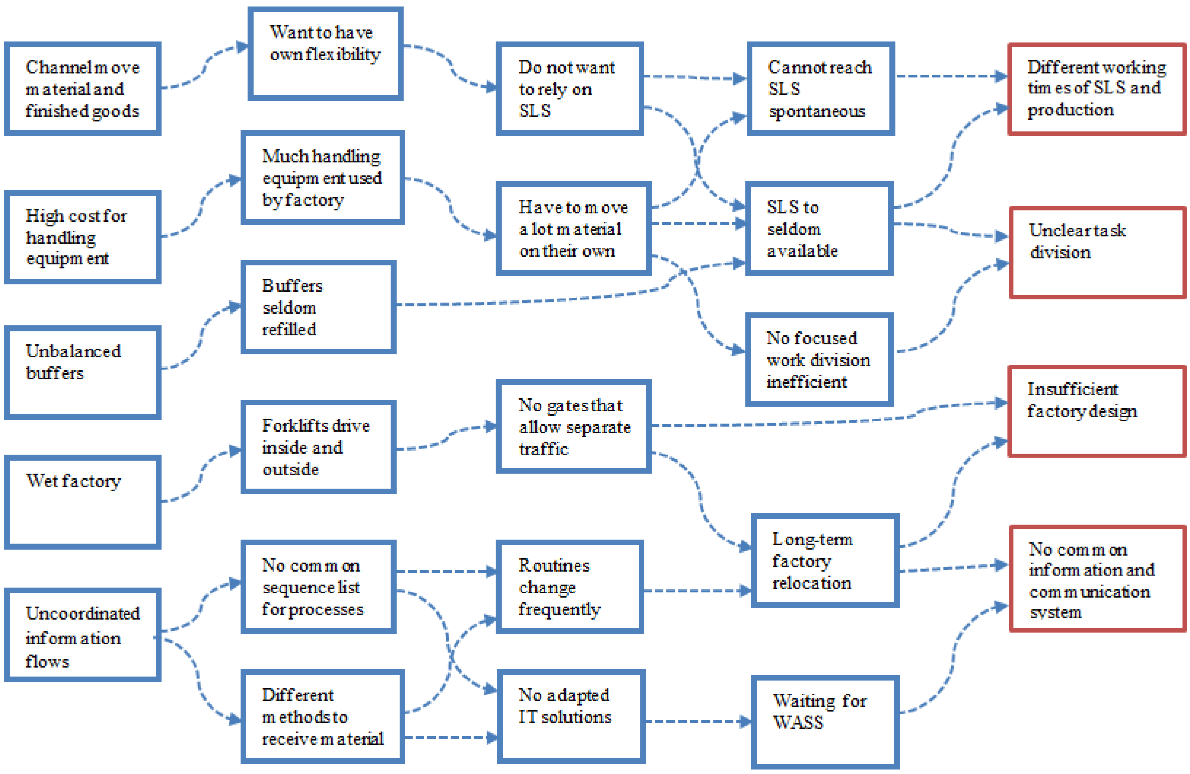


Figure 6.1: Root-cause map

6.2 Responsibility Analysis

Based on the theory part in chapter 3.4 about division of work and the purpose to reach a stage where production produce and logistics move material, the different material movement tasks need to be analyzed. As much material as possible should be handled by SLS but their activities are restricted by constraints as described in chapter 5.3. In the part 5.2 about task division an overview about how the different task are divided today was provided and all zones that are marked red, orange or violet are performed by the channels and should be in best case all taken over by SLS. But there exist different reasons and problems which cause that the channels perform these tasks today. By considering channel after channel these reasons and problems as well as possible improvements will be analyzed and summarized in a table for each channel. It may be the case that some solutions are mutual exclusive and one is superior to another or that some solutions have to be implemented together to work. By having the upcoming implementation of WASS in mind the situation and changes needs to be compatible.

6.2.1 *LT5*

For LT5 the channel carries out all material handling to the assembly as well as the packaging material on their own and need to get them from the intermediate component storage in the middle of the factory with a stacker (P2). This is the case because the way to the assembly and the end of the channel cannot be used by forklift trucks because the way is to narrow (P11). This is also the case for taking the finished goods from the channel (P8). The location of LT5 in the corner and surrounded by other channels makes it hard for SLS to reach LT5 and to visualize the demand for transportation. For the load carriers the same problem that SLS cannot reach the stacks of load carriers for return occurs. Furthermore, the rings come on EUR-pallets to the channel and finished products leave on EUR-pallets and that leads to problems in the central storage (P1) and that there is no reuse for half-pallets, collars and locks from cages and rollers. EUR-pallet covers will disappear with reliable operation of the E-heat treatment because they are just use on pallets from the A-heath treatment. Roller boxes are unproblematic moved to LR1 next to the channel. Because of the characteristics of the first machine pallets have to move one in time into the robot and SLS cannot support this task further. But on some weekends even the buffers of rings before the channel is empty and the channels have to get them by their own from the roller conveyors and need access to a forklift for that.

Table 6.1: Possible improvements responsibility analysis LT5

Problem	*Possible Improvement*
P11: Aisle between LT5 and LR1 not accessible for a forklift truck	S11: Reconstruct aisle between LT5 and LR1 <u>OR</u> S12. SLS uses stacker to reach finished products from LT5 and LR1
P2: Long distance to intermediate component storage	S2: Intermediate buffer zone closer to the channels
P8: Limited buffer zones in the end of the channel	S3: SLS more tasks, operates 24/7 and later WASS
P1: Central storage cannot handle EUR-pallets	S1: Rings, finished bearings and packaging material on half-pallets

6.2.2 *LT4*

In channel LT4 the components, packaging materials, and returned parts are moved by the channels operators from and to the intermediate component storage in the middle of the factory (P2). This need to be done one time per bearing type and that is approximately one time per day. The problem in this case why SLS does not perform these tasks is that they do not use the assigned areas close to the channel to place the material for the assembly there. Furthermore, because space is limited and new components are needed once a day problems occur based one the absence of SLS on weekends. The finished goods need also to be moved to the intermediate component storage from the end of the channel about every third hour because buffer areas are very limited and it is not possible to store them until SLS is available again (P8). For load carriers the major difficulty is that only the packaging material is transported on EUR-pallets with locks. They are not reused and accumulate to stacks that regularly need to be emptied (P3). All other load carriers are reused by LT4 or other channels. The rings need to be moved by the channel into the first machine but the times that the channel operators need to fill the empty ring buffer on weekends should be reduced.

Table 6.2: Possible improvements responsibility analysis LT4

Problem	*Possible Improvement*
P2: Long distance to intermediate component storage	S2: Intermediate buffer zone closer to the channels <u>OR</u> S3: SLS more tasks, operates 24/7 and later WASS
P8: Limited buffer zones in the end of the channel	S3: SLS more tasks, operates 24/7 and later WASS
P3: Not reusing load carriers within channel	S1: Rings, finished bearings and packaging material on half-pallets

6.2.3 *LT3*

In channel LT3 rings, components as well as packaging material is transported by SLS to the channel. This is very practical in assembly and packaging because they just take the parts they just need with minimized movements. Regarding the rings, they cannot be moved into the first machine by SLS in order to avoid additional handling by the channel since no kind of roller conveyor is in place (P6). Returned parts i.e. rings that wait for their assembly as well as all load carriers lack an assigned area and routine that enable the handling through SLS (P20). Finished product handling creates the biggest problems because they are so heavy and need to be handled one by one. The time window for this task is very narrow and SLS forklift driver would need to be available within about 20 minutes (P8).

Table 6.3: Possible improvements responsibility analysis LT3

Problem	*Possible Improvement*
P6: Move each pallet separately into first machine	S8: Roller conveyer before first machine
P20: Buffers not adapted to WASS or SLS handling	S9: Organise and structure buffer zones inside the channels, assign routines
P8: Limited buffer zones in the end of the channel	S3: SLS more tasks, operates 24/7 and later WASS

6.2.4 *LT2*

For LT2 it is hard to make clear statements about the division of transportation work because the channel is not finished yet and many changes occur now and in the future. But for the further establishment of LT2 is it especially important to know which services are available from SLS and with tasks they have to do on their own. Here the possibility to create operations that do not need to be readjusted to logistics is still there. For example it is important that not additional material handling by the channel is necessary to place the rings into the first machine (P6) Based on the availability of SLS buffer areas and other assigned places can be designed in a way that enables increased SLS operations and the implementation of WASS (P20). The channel design includes the idea of inflow of rings on one side and the outflow of finished bearings on the other side. The location of the channel has even the advantage that counterbalanced trucks can access the channel from both sides.

Table 6.4: Possible improvements responsibility analysis LT2

Problem	*Possible Improvement*
P6: Move each pallet separately into first machine	S 8: Roller conveyer before first machine
P20: Buffers not adapted to WASS or SLS handling	S9: Organise and structure buffer zones inside the channels, assign routines

6.2.5 *CARB*

Channel CARB has the advantage with a kind of circular flow that enables the direct accessibility of SLS trucks to the inflow of rings and the out flow of finished products. But the buffer spaces before and after the channel are quite small and handling of about one time per hour needs to be realizable in order to secure smooth production (P7, P8). In the current situation CARB is in the favorable situation to have a storage space next to the channel, which SLS delivers components and rings to. Only packaging material and finished bearings need to be moved longer distances by the channel operators. Furthermore, load carrier material is mainly reused and does not cause additional flows. With the removal of the CR3 roller channel from the E-factory the roller boxes can no longer just be moved to that channel, instead it must be included into the routines of the SLS operations. Another specialty of the CARB channel is that they process inner and outer rings in the same machines and to reduce set up times they first handle one kind of rings for the current bearing type and then the other kind. This makes it necessary to store the rings in between and a close by storage area is essential (P20).

Table 6.5: Possible improvements responsibility analysis CARB

Problem	*Possible Improvement*
P7: Limited buffer space in the beginning of the channel	S3: SLS more tasks, operates 24/7 and later WASS
P8: Limited buffer zones in the end of the channel	S3: SLS more tasks, operates 24/7 and later WASS
P20: Buffers not adapted to WASS or SLS handling	S9: Organise and structure buffer zones inside the channels, assign routines

6.2.6 *K30*

The channel for the largest bearings K30 is characterized by the need of special equipment because of the oversized parts used in the production. But K30 is still under construction and new machines and equipment will be added during 2012. This will reduce handling effort and give the possibility for SLS to supply K30 with rings. K30 has a relatively large buffer area at its end where components and packaging material is moved to by SLS. The irregular production makes it hard for SLS to know when they are needed to perform material handling (P4). In addition, it is important to know how heavy the product is in order to decide which kind of material handling equipment is required. Since the rings are too large to just be placed on any buffer area, returned flows have to be handled differently. Direct communication from K30 to SLS needs to be assured because WASS is not yet able to handle returned flows. Because the load carriers are oversized a reuse within the channel is not possible (P3) and reasonably stable return flows of this material need to be handled.

Table 6.6: Possible improvements responsibility analysis K30

Problem	*Possible Improvement*
P4: Irregular production and material needs	S3: SLS more tasks, operates 24/7 and later WASS OR S4: Communication device for channels and SLS
P3: Not reusing load carriers within channel	S9: Organise and structure buffer zones inside the channels, assign routines

6.2.7 *LR1*

As a roller channel LR1 does not need that much space for the input of materials and SLS already today handles these flows. But this supply does not always work without disruptions and the channel operators conduct transportation of material of their own from time to time (P4). To avoid this from occurring it must be made possible for to reach SLS at any time and to use their service. However, the main problem for LR1 is that packaging material is needed where the finished rollers are handled and this area is restricted to be used by a forklift truck in (P11). Therefore, long material movements from and to the intermediate component storage with packaging material and finished rollers have to be performed by the channel operators (P2). Hence, the channel operators are demanded to undertake a substantial part of the transportation process. Moreover, load carriers are reused and odd rollers are stored inside LR1. Because the CARB roller channel will be moved away from the E-factory this channel will not be considered further. The E-heat treatment handles their material movements on their own and will continue with that and therefore is it not considered separately in this part.

Table 6.7: Possible improvements responsibility analysis LR1

Problem	*Possible Improvement*
P11: Aisle between LT5 and LR1 not accessible for a forklift truck	S11: Reconstruct aisle between LT5 and LR1 OR S12: SLS uses stacker to reach finished products in LT5 and LR1
P2: Long distance to intermediate component storage	S2: Intermediate buffer zone closer to the channels
P4: Irregular production and material needs	S4: Communication device for channels and SLS

6.3 Equipment Analysis

In this section the material handling equipment used in the E-factory will be analyzed based on the theoretical chapter 3.2 about material handling. The purpose of this section is to evaluate and determine if the current material handling equipment is optimal for the requirements and demands of the E-factory and also to assess and examine if there is room for improvement of the present situation. In addition, the analysis is performed in order to reduce the high amount of material handling equipment, which in turn causes high costs to the E-factory. The future needs of the factory will be taken into consideration in this analysis. Moreover the equipment constraints identified in chapter 5.3 affect this analysis in terms of limitations that have an impact on the choice of material equipment.

Each channel’s current material handling equipment will be presented in an equipment analysis chart, which describes place of usage, main area of function, lifting features, current fork length and required fork length for movement. This gives the opportunity to get a clear description of the handling equipment’s main characteristics and it will also provide the necessary information about how the current equipment could be replaced with more efficient equipment or determine whether it is superfluous. An overview of all channels handling equipment and their purposed replacement is provided in Appendix 2. In addition, considerations about the working environment of the channel operators need to be taken into account since changing equipment should not create an inferior working environment but should instead improve it or stay the same. After having analyzed each channel’s material handling equipment a suggestion regarding alternative equipment will be provided which will function as a base for the solution creation in chapter 7.

The key problems from the chapter 5 that are most relevant for the equipment analysis and be examined are:

- P5: High costs because of too much handling equipment
- P14: Material handling equipment not adapted to current needs
- P15: Removal or replacement of Kentrucks

6.3.1 General Equipment Analysis

Material characteristics that affects choice of material handling equipment in the E-factory is material weight and size (see chapter 3.2). Since the maximum size that is going to be handled is either a half-pallet, EUR-pallet or an oversize pallet (K30) this is the restriction in terms of material size range in each channel. In terms of material weight when selecting and choosing alternative equipment the substitute or alternative material handling equipment must be able to carry the maximum load of the current equipment or it may be the case that equipment with less maximum load can perform the various tasks. During the channel wise analysis this cases will be identified and considered separately. In addition, all the leased movable handling equipment used in SKF’s E-factory is marked with an identification number of three or four numbers that will be used in this thesis to enable a clear assignment of improvement advice to the respective equipment.

6.3.2 Channel Equipment Analysis

6.3.2.1 LT5

In the current situation LT5 operates eight types of movable material handling equipment, which are used for various purposes. They are divided into three different categories Kentrucks (881,514, 879, 745, 879, 515), Pedestrian stacker (1295) and a Platform stacker (1043) (see Table 6.8). These will be analyzed in the following sections. Regarding the amount of equipment within LT5 and especially the Kentrucks in this case, it can be stated that they are not utilized sufficiently and therefore needs to be reduced or replaced by more inexpensive equipment in order to lower the costs of equipment in the E-factory (P5).

Table 6.8: Equipment analysis chart LT5

LT5	Place of usage	Main area of function	Lifting features	Equipment fork length currently	Fork lenght required for movement
881	Assembly, Inspection/transporting rings between assembly and processing	Lifting/transporting	Medium	Long	Short
514	Assembly, Inspection/transporting rings between assembly and processing	Lifting/transporting	Medium	Long	Short
879	Assembly, Inspection/transporting rings between assembly and processing	Lifting/transporting	Medium	Long	Short
745	Assembly, Inspection/transporting rings between assembly and processing	Lifting/transporting	Medium	Long	Short
515	Assembly, Inspection/transporting rings between assembly and processing	Lifting/transporting	Medium	Long	Short
1295	Transporting rings to robot	Lifting/transporting	High	Long	Long
1043	Transporting finsished products to bufferzone/Assembly	Lifting/transporting	High	Long	Long

Kentrucks

Table 6.8 shows the current characteristics and responsibilities of the Kentrucks (881,514, 879, 745, 879, 515) used in LT5. Their place of usage and main area of function is lifting and transporting components within the channel. However, after having observed the Kentrucks during some time it was obvious that they are most frequently situated in assembly where they used to lift pallets in an ergonomics position for the different components. In terms of lifting features the material need to be elevated to a “waist” high (medium) position that the operators are able to use them in assembly by creating an ergonomically correct working environment. In terms of fork length there is no reason for long forks since inside LT5 only half-pallets are used (P14). The only situations where there is a need for long forks in LT5 is when the rings are transported from the buffer point into the robot cell by 1295, since the rings come on EUR-pallets and when transporting finished products to the intermediate component storage. In addition, some consumables also come on EUR-pallets. Hence, when selecting alternative equipment to the Kentrucks the size of forks or table can be limited to a half-pallet.

Table 6.9 gives an overview about which alternative equipment for the Kentrucks in LT5 are possible (P15). The main alternative to the Kentrucks in LT5 are scissor tables. However, discussion with the channel operators must be made regarding the fact if one or two of the Kentrucks should be replaced with similar equipment in order to not create any unnecessary constraints on the activity within the channel. The stackers 1295 and 1043 that are in use in LT5 can be used in the same way as the Kentrucks are now since they have the same features.

In addition, if choosing scissor tables as an alternative to the Kentrucks one of the stackers or Kentruck alternative must be used to lift the load carriers onto the scissor tables if the scissor tables are not inset or integrated into the floor.

Table 6.9: Possible improvements equipment analysis LT5

LT5	Related problem	Possible improvements
881	P5, P14, P15	S6: Replace with scissor table or similar equipment
514	P5, P14, P15	S6: Replace with scissor table or similar equipment
879	P5, P14, P15	S6: Replace with scissor table or similar equipment
745	P5, P14, P15	S6: Replace with scissor table or similar equipment
515	P5, P14, P15	S6: Replace with scissor table or similar equipment
1295	P5	S7: Replace with more adapted equipment
1043	P5	S3: SLS more tasks, operates 24-7 and later WASS

Stackers 1295 and 1043

Table 6.8 displays the current characteristics and responsibilities of 1295 and 1043 in LT5. Their main area and place of usage are in the beginning and the end of the channel. In the beginning of LT5, 1295 collects rings from the internal buffer zone and moves the rings into the robot cell. In order to perform this operation long forks are required as long as rings come on EUR-pallets to the channel. In addition, sometimes the pallets are stacked on top of each other and therefore the truck moving the rings need to be able to separate and lift the pallets that are stacked on top of each other.

1043s main purpose currently is to transport finished products to the intermediate component storage in the E-factory as well as collecting complements and consumables from this area (see Table 6.8). In addition, 1043 is used in the assembly to lift load carriers in an ergonomic position. 1043 is required to have high lifting capabilities since it is used to stack components on top of each other and to function like a scissor table. Regarding fork length currently and required there is a need for long forks since the channel operators transports the finished products on EUR-pallets to the intermediate component storage. In addition, long forks enable the operators to transport twice as many half-pallets containing components at a time, which reduces their time away from production. Finally, empty wooden crates are currently transported on EUR-pallets which also require long forks for handling.

To make a decision about alternative handling equipment for the stackers 1295 and 1043 it is important to have the size and weight of the material that is moved in mind. Maximum size to move is EUR-pallets and the stackers in place today can lift 1200kg. An alternative to stacker 1295 would be to use a hand pallet truck that transports the rings between LT5 buffer zone into the robot cell. However, this is only possible if the rings are not stacked on top of each other when they arrive to the internal buffer zone in the beginning of the channel. The tasks 1043 performs could be executed by a forklift truck from SLS. However, this task can only be performed by a forklift truck from SLS if the aisle between LT5 and LR1 is changed. The task stacker 1043 performs in assembly could be alternatively handled with a scissor table or Kentruck alternative. Constraints such as turning point and accessibility presented in chapter 5.3 will impose problematic conditions for a forklift truck in the end of LT5. If these conditions are not altered or changed then the implementation and switching to a forklift truck is impossible.

Moreover, another alternative to the stacker 1043 would be to have SLS performing the tasks as the channel operators does with 1043 with the use of a similar stacker and not a forklift truck. Considerations regarding if this equipment will demand extra time from the SLS operators when switching between different equipment and if the equipment will have low utilization must be considered. Finally, regardless which alternative is chosen in terms of selection of material handling equipment for LT5, with the implementation of WASS there must be some way for the SLS operators to deliver components and collect finished products to and from LT5 and therefore some changes needs to be implemented and executed.

6.3.2.2 LT4

In the current situation at LT4 there are 8 types of moveable material handling equipment available, which are used for various purposes. They are divided into two different categories Kentrucks (1077, 1078, 1079, 1080, 1081, 1082, 1083) and a Pedestrian stacker (1076) (see Table 6.10). These will be analyzed in the following sections. Moreover, in terms of load carriers in LT4 only half-pallets are used except that packaging material is loaded on EUR-pallets. Lastly, concerning the amount of handling equipment within LT4 and especially the Kentrucks in this case, it can be observed that they are not utilized sufficiently and therefore needs to be reduced or replaced by more inexpensive equipment in order to lower the costs of handling equipment in the E-factory (P5).

Table 6.10: Equipment Analysis Chart LT4

LT4	Place of usage	Main area of function	Lifting features	Equipment fork length currently	Fork lenght required for movement
1077	Assembly	Lifting/transporting cages	Medium	Short	Short
1078	Assembly	Lifting/transporting rollers	Medium	Short	Short
1079	End of processing	Lifting inner rings	Medium	Short	Short
1080	Assembly	Lifting/transporting outer rings	Medium	Short	Short
1081	Beginning of processing	Lifting inner rings	Medium	Short	Short
1082	Assembly	Lifting/transporting inner rings	High	Short	Long
1083	Bufferzone	Transporting outer & inner rings to processing	High	Long	Short
1076	End of channel	Transporting finshed products to external bufferzone	High	Long	Long

Kentrucks

The current characteristics and responsibilities of the Kentrucks (1077, 1078, 1079, 1080, 1081, 1082, 1083) in LT4 can be seen in table 6.10. Their place of usage and main area of function are somewhat different. 1077,1078, 1080 and 1082 are situated in assembly were they are used to lift the different components in an ergonomics position and enables the operators to have an ergonomically correct working environment in terms of lifting features.

Currently, 1083 transports outer rings from LT4s buffer zone for further processing in to the robot cell. The need for long forks in this situation is not justified since LT4 only uses half-pallets. However, the long forks provide reduced transportation times since the operators place two half-pallets at a time in the robot cell. Moreover since the load carriers with rings come stacked on top of each other the need for handling equipment that has lifting capabilities is required unless the rings arrives to the channel without being stacked on top of each other. 1081 is used to lift pallets with inner rings in an ergonomics position before processing. This reduces fatigue in the operators since they do not have to bend down and reach for rings. 1079 has the same tasks as 1081, the difference is that it is used to lift pallets in an ergonomics position at the end of inner ring processing.

Since the Kentrucks needs to be replaced or removed in LT4, another handling equipment alternative needs to be found (P14, P15). An alternative for the Kentrucks 1077, 1078, 1079, 1080, 1081 and 1082 would be to replace them with scissor tables or a Kentrucks similar alternative (see Table 6.11). In addition, to the scissor tables in assembly the operators will also have access to a power driven hoist which is able to lift the blue plastic boxes containing rollers from the load carrier situated on the floor onto the assembly table without causing fatigue in the operators. The hoist will therefore act as a complement to the equipment that will replace 1078 since not all rollers arrive on half-pallets. Stacker 1076 can be used to lift the load carriers (half-pallets) onto the scissor tables if the scissor tables are not inset or integrated into the floor.

Table 6.11: Possible improvements equipment analysis LT4

LT4	Related problem	Possible improvements
1077	P5, P14, P15	S6: Replace with scissor table or similar equipment
1078	P5, P14, P15	S6: Replace with scissor table or similar equipment
1079	P5, P14, P15	S6: Replace with scissor table or similar equipment
1080	P5, P14, P15	S6: Replace with scissor table or similar equipment
1081	P5, P14, P15	S6: Replace with scissor table or similar equipment
1082	P5, P14, P15	S6: Replace with scissor table or similar equipment
1083	P5, P14, P16	S6: Replace with scissor table or similar equipment
1076	P5	S3: SLS more tasks, operates 24-7 and later WASS

In terms of fork length required for moving the material in channel LT4 it can observed that currently all the Kentrucks except 1083 have short forks in order to move and lift half-pallets. 1083 can be replaced with a hand pallet truck or a stacker with long forks. However, considerations regarding how to lift down pallets that are stacked on top off each other in LT4s buffer zone need to be made if a decision is taken to replace 1083 with a hand pallet truck. In addition, constraints such as turning point and accessibility presented in chapter 5.3 may cause implication when trying to use a stacker to move material into the robot and therefore needs to be carefully evaluated before replacing equipment.

Stacker 1076

Table 6.10 shows the current characteristics and responsibilities of 1076 in LT4. Its main area and place of usage is at the end of the channel. 1076 transport finished products to the intermediate component storage in the middle of E-factory and collect components and consumables for LT4. 1076 is required to have high lifting capabilities since it places half-pallets of finished products on top of each other before the products are transported to the intermediate component storage. Moreover, the components are frequently stacked on top of each other and therefore this further justifies the need for high lifting capabilities.

Regarding fork length currently and required long forks are demanded since the channel operators transports the finished products to the intermediate component storage. Long forks enable the operators to transport twice as many half-pallets in one round, which reduces their time away from production. In addition, the packaging material comes on EUR-pallets, which also justifies long forks. Regarding load capacity 1076 can carry a maximum load of 1000kg.

As the main problem of the equipment analysis of 1076 it can be found that it to some extent causes unnecessary cost for the E-factory (P5). An alternative would be to have SLS collecting finished products and transporting components and consumables to the channel internal buffer zone. If this scenario would be implemented the channel would need to have some form of power driven material handling equipment inside the channel in order for example to lift unit loads onto scissor tables or transporting products form internal buffer zone to the assembly area.

6.3.2.3 LT3

In the current situation in LT3 there are 5 types of material handling equipment, which can be divided into 3 different categories: three Platform stackers (1028, 1029, 1052), one forklift truck (963) and one Rider pallet truck (1177). These will be analyzed in the following sections and the overview can be seen in Table 6.12. The main problem regarding the material handling equipment in LT3 is related to the fact that some of the equipment has rather low utilization, which creates excess cost for the E-factory (P5). A general view regarding the equipment in LT3 is that some tasks can be outsourced to SLS which in turn will reduce the cost in the E-factory.

Table 6.12: Equipment analysis chart LT3

LT3	Place of usage	Main area of function	Lifting features	Equipment fork length currently	Fork lenght required for movement
963	End of channel	Lifting/transporting components & finished products	High	Long	Long
1177	Assembly	Collecting rings from external bufferpoint	High	Long	Long
1028	Assembly	Lifting/transporting rollers	High	Short	Short
1029	Assembly	Lifting/transporting rollers	High	Short	Short
1052	Beginning of channel	Lifting/transporting rings	High	Long	Long

Stacker 1028 and 1029

Table 6.12 shows the current characteristics and responsibilities of 1028 and 1029 in LT3. Their main area and place of usage is in assembly, where they transport half-pallets containing rollers from both internal buffer zone and external buffer zone to the assembly area. In addition, 1028 and 1029 are used to lift pallets in an ergonomics position in the assembly and have a lifting capacity of 1000kg. The rollers come only on half-pallets therefore the need for short forks. The lifting features of 1028 and 1029 provide the operators with easy access to the rollers. A problem according to the operators in LT3 is that 1028 and 1029 has limited battery capacity which demands that the trucks are frequently charged (P14).

As an alternative to the two stackers 1028 and 1029 in LT3 could be to have one scissor table. The same benefits that are described earlier in chapter 3.2.3 when replacing Kentrucks with scissor tables will be achieved if replacing the stackers in LT3 with scissor tables. However, both of the stackers cannot be replaced since there must be one left supplying the assembly station and scissor table with new rollers. In addition, the constraints turning point and accessibility described in chapter 5.3 prohibits other equipment such as a forklift truck or similar to reach the assembly station. Moreover the remaining truck should be replaced with another new truck since the battery power creates problematic working conditions for the operators. A better and cheaper alternative for a stacker would be to have equipment that has the same features a Kentruck.

Table 6.13: Possible improvements equipment analysis LT3

LT3	Related problem	Possible improvements
963	P5	S3: SLS more tasks, operates 24-7 and later WASS
1177	P5	S5: Remove without replacement
1028	P5,P14	S6: Replace with scissor table or similar equipment
1029	P5,P14	S6: Replace with scissor table or similar equipment
1052	P5	S8: Roller conveyer before first machine

Stacker 1052

1052 is used in the beginning of the channel were it lifts and transports inner and outer rings from LT3s internal buffer zone to initial processing. Long forks are required since the rings come on EUR-pallets. Furthermore, 1052 can carry a maximum load of 1500kg. An alternative would be to replace the stacker 1052 by a roller conveyor in the beginning of the channel (P5). According to Jonsson and Mattsson (2008), conveyor system can be used to transport material form one point in the facility to another. This will create benefits such as that the rings will be placed on the roller conveyor immediately when they arrive from the roller conveyers instead of on the floor in the internal buffer zone. This will reduce the number of movements of pallets and create a more smooth running operation.

Furthermore, there is an extensive amount of different types of conveyor systems such as floor based roller conveyors, chain conveyors and roof mounted hanging conveyors (Jonsson and Mattsson, 2008). Therefore it is crucial to choose the optimal one for LT3. Moreover, installing roller conveyer will eliminate the need for the scissor tables that are currently situated in the beginning of LT3. Finally, the empty EUR-pallets left on the conveyor can easily be removed if the roller conveyor is made height adjustable. This eliminates the possibility of fatigue and exhaustion of the operators since they can easily slide the pallets of the conveyor and on to the floor.

Forklift Truck 963

As it can be seen in Table 6.12 963's core purpose is to collect cages and wooden crates from the intermediate component storage and transport/lift finished products from the end of LT3 to the channels internal buffer zone. The lifting features of the truck are required since the truck must be able to stack for example the empty wooden crates on top of each other. Since the maximum size that is going to be handled are oversized wooden crates (1400x1400mm) this is the restriction in terms of material size range. 963 can carry a maximum load of 2000kg.

The main problem regarding 963 is that it generates a substantial amount of costs to the E-factory (P5). Considering the tasks 963 performs, there is no alternative material handling equipment. 963 is versatile and an important handling equipment for LT3 in order to perform the core duties in LT3, such as transporting finished bearings in wooden crates. But the forklift truck used for these tasks does not necessarily have to be operated by the channel. Instead as an alternative, SLS could perform the tasks with their forklift trucks, and reduce the excess costs for handling equipment in the E-factory.

Rider Pallet Truck 1177

Table 6.12 shows the current characteristics and responsibilities of 1177. 1177s main purpose currently is to collect processed inner and outer rings (white rings) from the intermediate component storage in the middle of the E-factory. The channel operators describe 1177 to be somewhat easier to maneuver in the narrow aisles compared to a forklift truck. However, this truck is rather limited since it has the lifting features of a low-lifter and can therefore not stack components and pallets on top of each other. In terms of fork length currently and required, the ring size in LT3 demands that they are transported on EUR-pallets which generate the need for long forks. In addition, 1177 can carry a maximum load of 2000kg.

Regarding 1177 there is no fundamental and essential task for this truck when the E-factory is completed according to the target layout that can be seen in Figure 5.2 and will therefore create unnecessary costs for the E-factory when it is complete (P5). However, in the current problematic situation regarding the limited space in the aisles when collecting rings from the intermediate component storage it will be hard to remove this truck. In the current situation there is no alternative handling equipment to replace 1177 with. However, when the target layout of the E-factory has been accomplished and the accessibility and turning point in the affected aisles has been improved 1177 will be superfluous and can therefore be removed from the E-factory.

6.3.2.4 LT2

In the current situation at LT2 operates 2 different types of material handling equipment, which are used for various purposes. They consist of one Platform Stacker (1164) and one Kentruck (989). These will be analyzed in the following sections and the overview is provided in Table 6.14.

Table 6.14: Equipment analysis chart LT2

LT2	Place of usage	Main area of function	Lifting features	Equipment fork length currently	Fork lenght required for movement
989	Begining of channel	Lifting/transporting inner rings between processing and inspection	Medium	Short	Short
1164	Face grinding	Lifting/Transporting rings between assembly and face grinding	High	Long	Long

In the analysis of the material handling equipment in LT2 considerations must be made regarding the fact that the channel is not yet complete. In the current situation only inner rings are processed in the E-factory. The remaining components and assembly is still situated in the old C-factory. LT2 will not be complete until 2013.

Kentruck 989

Table 6.14 shows 989’s current place of usage and main area of function which is in the beginning of the channel were it is used to lift rings out of the processing machine and transport it to inspection in the end of LT2 and then back again for further processing. The core purpose of Kentruck 989 is to reduce fatigue in the operators since they do not have to bend down and reach for rings, hence eliminating any inconvenient working position. The short forks are demanded since the accessibility and turning point inside the channel limits the use for long forks. Moreover, all the inner rings currently processed in LT2 are capable of being transported on half-pallets. 989 can carry a maximum load of 800kg and the alternative equipment should be able to carry a load that correspond the maximum carry load of 989 due to the size and weight of the outer rings.

The main problem regarding 989 is that it needs to be replaced with another kind of handling equipment (P15). In the current situation it is hard to find suitable replacement equipment for 989 considering the current situation of LT2. Therefore, it is suggested that LT2 keeps 989 until as late as possible or replace it with equipment that has the same features as a Kentruck. A new equipment analysis should be performed when the channel is complete in order to find the optimal alternative.

Table 6.15: Possible improvements equipment analysis LT2

LT2	Related problem	Possible improvements
989	P15	S6: Replace with scissor table or similar equipment
1164	P5	S3: SLS more tasks, operates 24-7 and later WASS

Stacker 1164

The stacker 1164s main area and place of usage is in transporting and lifting inner rings between the face grinding and LT2 (see Table 6.14), which is situated approximately 50 meter away from LT2. The lifting features are required in order to get the rings leveled with the face-grinding machine. Furthermore, long forks are required since the rings arrive on both EUR-pallets and half-pallets and 1164 can carry a maximum load of 1500kg.

As it can be seen in Table 6.15 the task 1164 will perform in the future can also be performed of a forklift truck as an alternative, which not necessarily need to be operated by the channel (P5). However, in terms of equipment constraints such as turning point and accessibility it is not possible to give definite suggestion since the channel is not complete and changes in factory layout might impose problems for the operation of a forklift truck from SLS in LT2. Therefore, it is suggested that the channel should keep 1164 until it is complete and which a new equipment analysis can be performed.

6.3.2.5 CARB

In the current situation CARB operates two types of material handling equipment, one Platform stacker (1184) and one Kentruck (803). These will be analyzed in the following sections and the overview is presented in Table 6.16. Special considerations that need to be made regarding CARB are that the channel only has the ability to process either inner or outer rings at a time. Therefore, after having processed all the inner rings in one batch the operators has to move them outside the channel to CARBs own buffer zone located near the channel in order to give room for the outer ring. After they are both processed they are moved again inside the channel for assembly. Finally CARB is currently the only channel with roller conveyers in the beginning, which enables a smooth flow of rings into the channel. Regarding the amount of handling equipment in CARB it was found that the number of handling equipment is not the main concern since there are only two of these in the channel. However, if 803 and 1281 could be replaced with only one sort of handling equipment then it would reduce some of the high costs of too much handling equipment in the E-factory

Table 6.16: Equipment analysis chart CARB

CARB	Place of usage	Main area of function	Lifting features	Equipment fork length currently	Fork lenght required for movement
803	Inside of channel	Multiple purposes	Medium	Short	Short
1281	End/Beginning of channel	Lifting/Transporting rings and finished products	High	Long	Long

Kentruck 803

Table 6.16 shows the current characteristics and responsibilities of 803 in CARB. Its place of usage and main area of function is in the middle of the channel where it is used for various purposes such lifting pallets in an ergonomics position for inspection of the components before assembly. It is also used to lift down half-pallets that are stacked on top of each other. The operators are very dependent of this equipment and expressed deep concern when they heard that 803 needs to be replaced in the near future (P15). The short forks are justified since CARB only use half-pallets. In addition, the lifting features of 800kg are suitable for the tasks performed by 803. Moreover, the limited space inside the channel demands that replacement equipment needs to be rather compact and small.

An alternative for 803 would be either pedestrian stacker or a Kentruck alternative (see Table 6.17). This is motivated by the information explained earlier in chapter 3.2.3. Moreover, the operators need to have the ability to lift down pallets that are stacked on top of each other, which eliminates the possibility to only use a scissor table inside the channel. One suggestion is that the channel operators test a pedestrian stacker with short forks inside CARB in order to see if constraints such as accessibility and turning point impose problematic conditions when using a pedestrian stacker inside the channel.

Table 6.17: Possible improvements equipment analysis CARB

CARB	Related problem	Possible improvements
803	P5, P15	S7: Replace with more adapted equipment
1281	P5	S3: SLS more tasks, operates 24-7 and later WASS

Stacker 1281

The place of usage and main area of function of 1281 is in the end/beginning of the channel where it used to collect components and transport finished products from and to E-factory's intermediate component storage. In addition, it is also used for moving processed inner and outer rings to CARB's internal buffer zone before they are moved to assemble by 803. The long forks are motivated since the channel operators collect components and deliver finished bearings which eliminates unnecessary transportation between CARB and E-factory's intermediate component storage. The height features are warranted since 1281 needs to be able to lift the ring onto the roller conveyor placed before the machine. In addition, 1281 has a lifting capacity of 1500kg, which is suitable for the tasks carried out. The main problem regarding 1281 is the high costs it generates for the E-factory (P5).

The alternative material handling equipment for 1281 would be to use a forklift truck to perform the respective tasks. This type of handling equipment has the same characteristics such as 1281 in terms of lifting capabilities in height and weight. Since CARB has roller conveyors in the beginning and end of the channel which are both located close to the main aisle of the E-factory it is not even necessary that the channel has to carry out this material movements and the forklift trucks of SLS could be used instead.

6.3.2.6 K30

In the current situation at K30 there are 5 different types of material handling equipment in use. They consist of one Platform pallet truck (1227), one Platform stacker (974), one Rider stacker (1268), one Rider pallet truck (1265) and one forklift truck (1266). In the analysis of the handling equipment in K30 considerations must be made regarding the fact that K30 will not be complete until the end of 2012. What remain to be finished are roller conveyors for the rings to be transported upon and additional processing machines. K30 has the same general problem regarding the high costs related to the amount of material handling equipment that is located within the channel (P5).

Table 6.18: Equipment analysis chart K30

K30	Place of usage	Main area of function	Lifting features	Equipment fork length currently	Fork lenght required for movement
1227	End of channel	Lifting/transporting material	Low	Long	Long
974	Assembly	Lifting rollers	High	Short	Short
1268	Assembly/End of channel	Lifting/transporting rings wodden crates and finished products	High	Extra long	Extra long
1265	Assembly/End of channel	Lifting/transporting rings wodden crates and finished products	Low	Extra long	Extra long
1266	Beginning of channel/End of channel	Lifting/transporting rings	High	Extra long	Extra long

Platform Pallet Truck 1227

The current characteristics and responsibilities of 1227 can be seen in Table 6.18 and its main area and place of usage is transporting and lifting material in channel K30. 1227 has no clear responsibilities and is used as an alternative to the other equipment. In addition, 1227 has been taken to the E-factory from the old C-factory where it had more precise purposes. The low lifting features can be motivated since 1227 only has to transport material and not stack unit loads upon each other. Furthermore, the long forks provide 1227 with versatile utility and enable to move both half and EUR-pallets.

Since 1227 does not have any clear responsibilities it can be regarded as superfluous (see Table 6.19) and will not be necessary to have when K30 is completed in 2012 and generates currently only extra cost for the E-factory (P5). Furthermore, when recently observed the truck was parked uncharged in K30, which only strengthens the fact that 1227 does not serve any purpose. In addition, the channel operators do not feel that 1227 is necessary to keep in the channel.

Stacker 974

The main area and place of usage of 974 is transporting and lifting unit loads containing rollers for the bearings produced in K30 (see Table 6.18). In order for the channel operators to be able to reach the rollers in a suitable position the handling equipment is required to lift the unit load to a medium waist high position. Furthermore, since the rollers only come on half-pallets the short forks are considered enough and do not need to be replaced by long forks. The problem with 974 is only related to the costs it imposes for the E-factory (P5). However, it was found the replacement equipment for 974 to be limited and therefore suggest that the channel in the current situation should keep 974 since switching to another alternative could worsen the working conditions for the channel operators

Table 6.19: Possible improvements equipment analysis K30

K30	Related problem	Possible improvements
1227	P5	S5: Remove without replacement
974	P5	none
1268	P5	S3: SLS more tasks, operates 24-7 and later WASS
1265	P5	none
1266	P5	S3: SLS more tasks, operates 24-7 and later WASS

Rider Stacker 1268

1268s main area and place of usage is lifting and transporting wooden crates and finished products in the end of the channel (see Table 6.18). The high lifting features of 1268 are motivated since it has to be able to lift the empty wooden crates and boxes containing cages that are stacked on top of each other and transport them from the internal buffer zone to assembly. In addition, the compact body structure of 1268 enabled by outriggers makes the truck more suitable when constraints such as accessibility and turning space can create problems in the assembly at K30. The operators find this equipment easy to use and not as bulky as the forklift truck 1266.

Regarding fork length required and currently in use in 1268 the extra-long forks are motivated since the bearings size in K30 ranges up to 2300mm in outer diameter (see chapter 2.2.1). These large bearings demand oversize wooden crates to be used and regular forks can only carry loads up to 1200mm, which correspond to the length of a normal EUR-pallet would be too short for this task. Therefore the main problem is the high cost that 1268 generates for the E-factory (P5).

Despite 1268s compact body structure and high maneuverability there are not enough incentives to keep 1268. In addition, the limited lifting capacity in terms of weight creates additional reasons for not keeping the truck, especially when K30 is complete. In addition, it could be observed that the space in K30s assembly area and internal buffer zone will provide enough accessibility and turning point for a forklift truck from SLS to operate in (see Table 6.19). Moreover, if 1265 is decided to remain in the channel it can also be used as a substitute for 1268.

Rider Pallet Truck 1265

The current characteristics and responsibilities of 1265 in K30 can be seen in Table 6.18. Its main area and place of usage is lifting and transporting wooden crates and finished products in the end of the channel. The main difference between 1265 and 1268 is that 1265 can carry heavier loads than 1268 (up to 4500kg). This creates an advantageous situation for the channel operators since they can transport all the bearings produced in K30 except the ones that exceed 4500kg. If the weight of the bearing exceeds 4500kg the channel operators will contact SLS who will come and pick up the bearing with their oversize diesel driven truck. Moreover another thing that distinguishes 1265 from 1268 is that 1265 is a low-lifter which only purpose is to transport the material from one point to another without stacking the material on top of each other, this justifies the low lifting feature. With regards to the extra-long forks they are motivated since the bearings size in K30 ranges up to 2300mm in outer diameter. As said before these large bearing demands oversize pallets and wooden crates to be used and regular forks can only carry loads up to 1200mm which correspond to the length of a normal EUR-pallet. Although the problem with 1265 is related to cost to the E-factory (P5), switching or replacing 1265 will only transfer the cost to another cost unit.

This specific handling equipment is considered to be necessary to keep unless K30 is provided with a forklift truck that is able to carry loads up to 4500kg. However, one must bear in mind that if 1265 would be replaced by a forklift truck the forklift truck would be much more bulky and unpractical weighing approx. 8000kg compared to 1256, which weigh only 1500kg. In addition, constraints such as accessibility, turning space and factory floor presented in chapter 5.3 will also need to be considered if choosing this alternative equipment.

Forklift Truck 1266

The main area and place of usage of 1266 is to transport inner and outer rings from the intermediate component storage to the beginning of the channel (see Table 6.18). Due to the construction of the channel it has also been used for additional purposes such as transporting finished products in the end of the channel. The extra-long fork lengths are motivated for the same reason as explained previously for this channel.

Currently the forklift truck 1266 is necessary since the other trucks in K30 are not capable of both lifting and transporting components that exceeds 1600kg (1268). In addition, a forklift truck is considered to have features such as higher maneuverability and more versatility than 1268. But it is not required that the forklift truck used for this task is operated by the channel, instead SLS could perform this with their forklift trucks and this would reduce the total cost for handling equipment in the E-factory (P5).

6.3.2.7 LR1

In the current situation at the roller channel LR1 there are 7 types of moveable material handling equipment, which are used for various purposes. They consist of 3 different categories one forklift truck (780), two Pedestrian stackers (1294, 1038) and four Kentrucks (510, 671, 546, 157221). Table 6.20 shows an overview of all of them and in the following they will be analyzed separately.

Special features regarding LR1 that need to be taken into consideration are that half of the rollers are transported to the RK-factory which is situated next to the E-factory for tumbling after having been processed inside LR1 and before coming back for further processing to LR1. This creates an additional transportation task since the rollers need to be transported outside the E-factory and back again to LR1. Moreover, the rollers arrive to LR1 initially in grey metal boxes. And before and after the tumbling process the rollers are in green metal boxes. Concerning the amount of handling equipment within LR1 and especially the Kentrucks in this case, it can be identified that they are not utilized sufficiently and therefore needs to be reduced or replaced by more inexpensive equipment in order to lower the costs for material handling equipment in the E-factory (P5).

Table 6.20: Equipment analysis chart LR1

LR1	Place of usage	Main area of function	Lifting features	Equipment fork length currently	Fork lenght required for movement
510	Robot cell	Lifting/transporting rollers	Medium	Long	Short
671	Assembly	Special equipment lifing/transporting green metal boxes	Medium	Special forks	Special forks
546	Assembly	Lifting/transporting rollers	Medium	Long	Short
157221	Assembly	Lifting/transporting rollers	Medium	Long	Short
780	Beginning of channel	Transporting rollers to and from RK-factory	Medium	Long	Short
1294	Beginning of channel	Collecting material from bufferzone/transporting rollers inside LR1	Medium	Long	Short
1038	End of channel	Lifting/transporting rollers inside LR1	High	Long	Long

Kentrucks

Table 6.20 shows the current characteristics and responsibilities of the Kentrucks (510, 671, 546, 157221) used in LR1. The main problem with the Kentrucks is that they need to be removed and replaced due to reasons explained in chapter 3.2.3. Moreover the amount of Kentrucks in LR1 causes excess cost for the E-factory and therefore if possible needs to be reduced in numbers (P5).

The Kentrucks place of usage and main area of function is lifting and transporting rollers that are placed on different load carriers within the channel. However, after having observed the Kentrucks 510, 546 and 157221 some time it could be seen that they are most frequently situated in assembly where they function as scissor tables for the rollers. In terms of lifting features the material need to be elevated in “waist” high (medium) position in order for the operators to be able to use them in assembly, creating an ergonomically correct working environment. Besides from acting as a scissor table, 510 currently takes out the rollers that are sorted in the robot cell in LR1. The Kentruck 671 is equipped with special forks that are designed to lift the green metal boxes that are used inside LR1. Currently no other equipment can be used for similar operation.

The Material characteristics that affect the alternative choice for Kentrucks (510, 671, 546, 157221) in LR1 are material weight and size. Since the maximum size that is going to be handled is a half-pallet than this is the restriction in terms of material size range (800x600mm). The Kentrucks can carry a maximum load of 800kg. The alternative equipment should be able to carry a load that correspond this maximum load because it is suitable for this task.

As an alternative for 510, 546 and 157221 a scissor table or Kentruck similar alternative would be suitable to replace the current equipment with (see Table 6.21). This is motivated by the information explained earlier in chapter 3.2.3. If choosing a scissor table considerations needs to be made on whether or not the table needs to be power driven or if it can be operated by manual force. Moreover, the channel operators have their own suggestion regarding the problem with the Kentrucks. They recommend a movable roller conveyer to put the half-pallets or blue plastic boxes on with the use of the stackers 1294 or 1038. The movable roller conveyer enables a more versatile and flexible working environment then for example a scissor table. This has to be a valid alternative since it will be more ergonomically efficient than a scissor table. Special concerns need to be made regarding the replacement of 510 since this equipment is used to take out the rollers that are sorted in the robot cell. Therefore as a suitable alternative a hand pallet truck can be used to take out the rollers from the robot cell and after this movement, 1038 can be used to lift down the half-pallet containing the rollers and replace it with a new one. Regarding 671, a pneumatic or electric hand held hoist like the one in LT4 with customized forks can be alternatively used to lift the green metal boxes.

Table 6.21: Possible improvements equipment analysis LR1

LR1	Related problem	Possible improvements
510	P5,P15	S6: Replace with a scissor table or more adapted equipment
671	P5,P15	S7: Replace with more adapted equipment
546	P5,P15	S6: Replace with a scissor table or more adapted equipment
157221	P5,P15	S6: Replace with a scissor table or more adapted equipment
780	P5	S3: SLS more tasks, operates 24-7 and later WASS
1294	P5	none
1038	P5	S3: SLS more tasks, operates 24-7 and later WASS

Stackers 1038 and 1294

1038 and 1294 main place of usage and main area of function is lifting and transporting rollers that are placed on half pallets throughout the channel. 1038 and 1294 can carry a maximum load of 1000kg respectively 1200kg which is suitable for their tasks. The main problem related to the stackers is the costs they generate for the E-factory (P5).

Alternative equipment for 1038 and 1294 is currently hard to suggest. The layout of the channel imposes problems for an alternative solution. However, in the end of the channel a forklift truck operated by SLS could be used instead of 1038 if the constraints accessibility and turning point presented in chapter 5.3 could be overcome. This would create a situation where only 1294 is available in the channel. Moreover, a hand pallet truck could be used as a alternative to 1294. In addition, if one of the Kentrucks in LR1 is replaced with a similar alternative this can also be used as a complement or alternative to the stackers in LR1.

Forklift Truck 780

Its place of usage and main area of function for 780 is lifting and transporting rollers between the E-factory and RK-factory. The lifting features are demanded since 780 moves both inside and outside the E-factory. The long forks are required in order to collect enough half-pallets when driving to the RK-factory and back. Because 780 is a forklift truck it is one of the material handling equipment that generates the most cost for the E-factory (P5) and therefore needs to carefully evaluated on whether or not it can be replaced or removed from the E-factory. As a possible improvement for 780 the assignments of the truck could be outsourced to SLS and thereby reducing the excess cost for the E-factory. However, in order to execute this strategy SLS would need to be available 24-7, which will also be required of them in order to function along with the implementation of WASS.

6.3.2.8 E-Heat Treatment

In the current situation the E-heat treatment operates 3 types of material handling equipment, which consist of 2 different categories, two forklift trucks (1181 and 1182) and one Platform stacker (1184). Based on the information in Table 6.22 they will be analyzed in the following.

Table 6.22: Equipment analysis chart E-heat treatment

Place of usage	Main area of function	Lifting features	Equipment fork length currently	Fork lenght required for movement
End of channel	Lifting/transporting rings from the end of Heaton 2 to the E-factories roller conveyer	High	Long	Long
End of channel	Lifting rings in the manual packing station in the end of Heaton 2	High	Long	Long
Beginning of channel	Lifting/transporting rings from the roller conveyers in EHT to the beginning of Heaton 2	High	Long	Long

Forklift Trucks 1181 and 1182

These handling equipment are used for various purposes in the E-heat treatment. However, their main area of function is to transport unprocessed rings from the roller conveyers in the E-heat treatment to the beginning of Heaton 2 and also deliver and place hardened rings to the roller conveyers inside the E-factory.

Stacker 1184

1184 is used as an alternative to the use of 1181 and 1182 in the E-heat treatment. The channel operators find 1184 to be especially useful in the manual packing station in the end of Heaton 2 since the forklift trucks are larger and more unpractical to use in this specific area. In the current situation there is no alternative to the kinds of handling equipment used in the E-heat treatment since the equipment is utilized satisfactory. Moreover, when Heaton 4 is operational the capacity utilization of the material handling equipment in the E-heat treatment will be even larger.

Therefore, in the light of the current situation there will be no suggested improvements regarding the current material handling equipment in the E-heat treatment. However, when Heaton 4 is operational a new analysis regarding the need for material handling equipment in the E-heat treatment should be performed.

6.4 Environment Fitness Analysis

In this section the environment in the E-factory will be analyzed and compared to the theoretical chapter 3.3 about factory layout. The purpose of this section is to evaluate and determine if the layout and environment is optimal for the requirements and demands of the E-factory and also to assess and examine if there is room for improvement of the present situation. First, a general environment fitness analysis regarding the layout and environment in the E-factory will be presented and compared to the available literature in chapter 3.3 and chapter 5.4 regarding future layout. Secondly, for each channel’s current layout is an environmental fitness analysis conducted, which will seek to analyze each channel’s buffer zone in the beginning and end of the channel. This analysis will be governed by the coming implementation of WASS. Regarding incoming components, such as rings, cages or rollers WASS requires two buffer zones for each unit load (EUR or half-pallet) containing components. In terms of finished products in the end of the channel's buffer zone a time window will control this constraint and hence will create the size of buffer zone required for finished products. A time window is defined by the time from when a task initially can be performed until when it must be finished or complete.

Moreover all the pictures concerning the E-factory's layout and the E-heat treatment are taken from the target layout figure presented in chapter 5.4 and modified in order to give a more descriptive view of the analysis. After having analyzed the environmental fitness of each affected area suggestions regarding improvement of the current layout or environment will be provided and this will function as a base for the solution creation in chapter 7.

6.4.1 General Environment Fitness Analysis of the E-factory

The general condition of the E-factory's current layout is that it is hard to comprehend at the moment due to the construction that is currently in progress. Therefore, this must be taken into consideration when performing this analysis.

6.4.1.1 Aisles

Regarding the aisles in the E-factory and the E-heat treatment, they are not divided into separate lanes for walking and use of handling equipment (P10). In order to prevent any accidents from happening in the E-factory and E-heat treatment the aisles should be divided in to separate lanes for equipment and walking (Ruddell, 1961). The aisles widths in the E-factory are designed upon transportation frequency in each channel. The so-called main aisles (see Figure 6.2) in the E-factory are wider than the branch aisles in order to cope with the more intense traffic pattern.

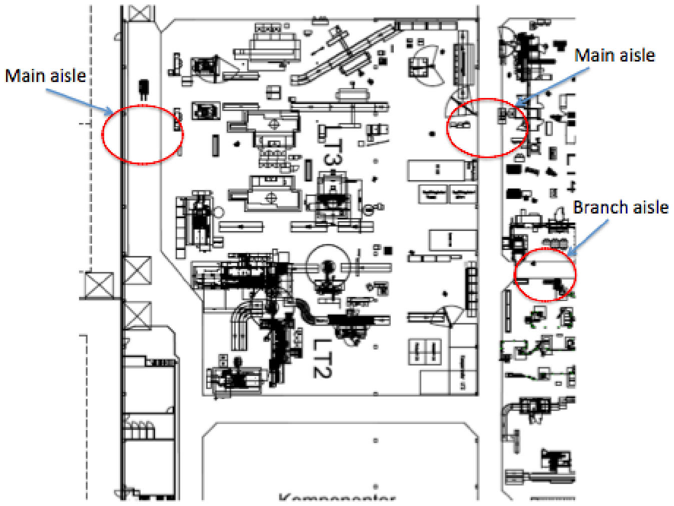


Figure 6.2: Main and branch aisles in the E-factory, Source: SKF (modified)

Another concern regarding the aisles in the E-factory is the branch aisle between LR1 and LT5 (see Figure 6.3). The problem with this aisle currently is that it is prohibited to use a forklift truck in this area which eliminates the possibility for SLS to collect finished products and deliver components to and from the buffer zones in LT5 and LR1 (P11). In addition, the operators are limited to only use stackers to transport the components and finished products to the intermediate component storage. This reduces their time of performing their core task, producing roller bearings. Therefore in order for SLS to collect and deliver components and finished products the aisle must be altered and adjusted to meet the demands of a forklift truck from SLS.

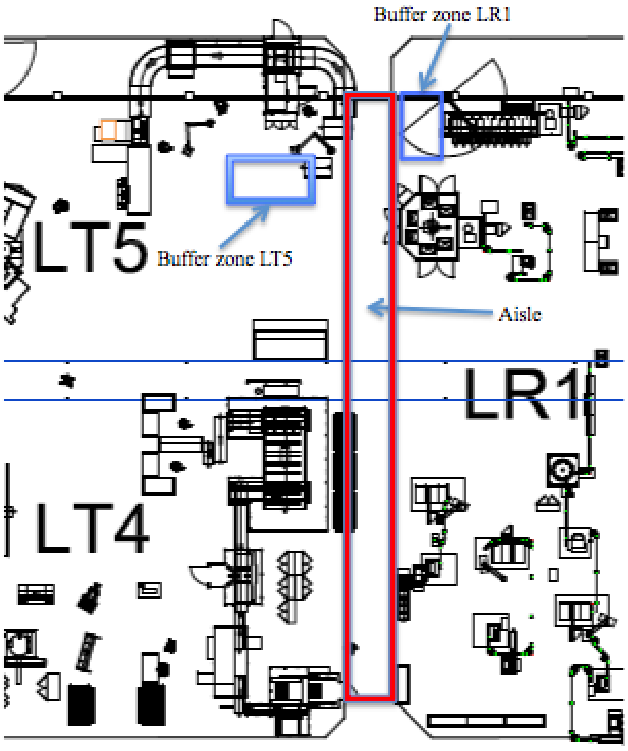


Figure 6.3: Aisle between LR1 and LT5, Source: SKF (modified)

Table 6.23: Possible improvements environment fitness analysis aisles

Problem	*Possible Improvement*
P10: Main aisles not divided in people and vehicle traffic	S10: Divide aisles into people and traffic
P11: Aisle between LT5 and LR1 not accessible for a forklift truck	S11: Reconstruct aisle between LT5 and LR1

6.4.1.2 Floor Bearing

Regarding the floor bearing capacity in E-factory, the largest bearings produced in K30 are limited to only be transported in the aisles marked with red arrows in Figure 6.4. According to Ruddell (1961), changes in the structural support of the building or factory should only take place in certain part of the building and not throughout the entire structure. Therefore, the project management of the E-factory has decided only to increase bearing capacity in the section that concerns K30. The remaining part of the factory has the structural limit to cope with the bearings produced in K30 together with the required handling equipment. Furthermore, the wooden crates and boxes containing cages are too large to be transported elsewhere than through the gate close to channel K30 (see Figure 6.4).

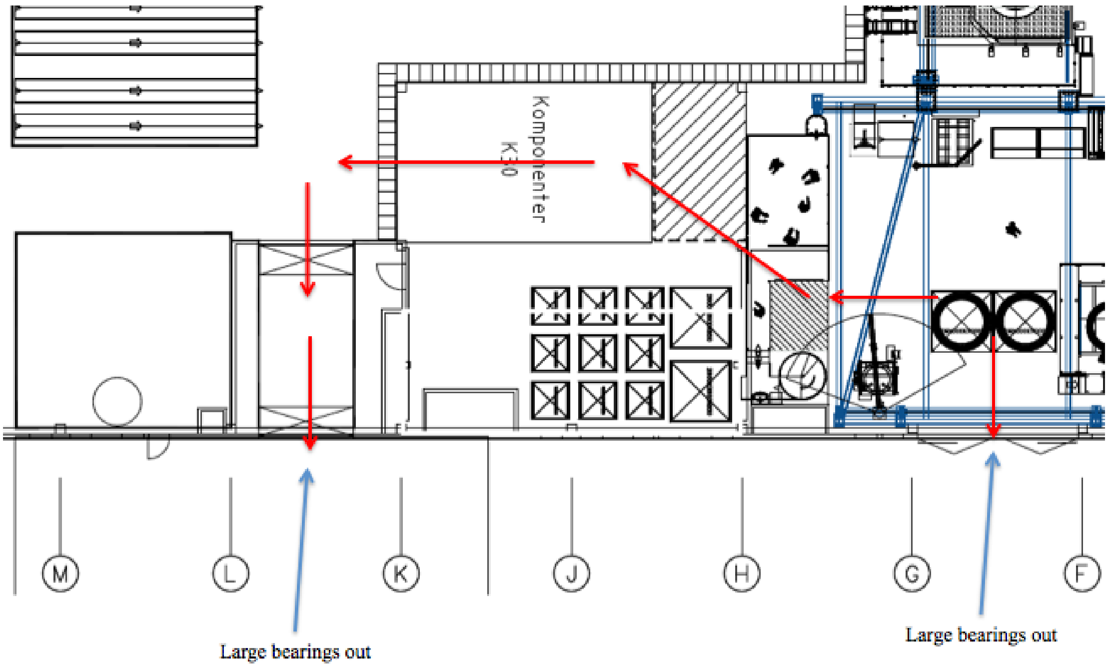


Figure 6.4: Consolidated floor bearing capability, Source: SKF (modified)

6.4.1.3 Clean Factory

E-factory

The management in the E-factory and the E-heat treatment has expressed their concern regarding the fact that there are no clear restrictions or limitations regarding which material handling equipment that should be used inside and outside the factory in order to avoid a wet and dirty factory (P13). Furthermore, the current factory layout prohibits this type of restrictions, because when the trucks/trailers containing components arrive outside the E-factory they are offloaded and the components are placed directly on to the ground outside the E-factory with limited protection from rain and storm. Currently there is no type of on/off loading dock with weather protection, only a roof in front of one gate that provides limited protection from weather, but this roof is too low for the trucks to park under.

Table 6.24: Possible improvements environment fitness analysis clean factory

Problem	*Possible Improvement*
P13: Wet and dirty factory	S13: Separate inside and outside forklift drivers <u>OR</u> S15: New porch roof with wind protected shelter
P17: Limited space inside the E-factory	S14: Loading dock with storage area

Therefore it is suggested to build a loading dock that is lowered in to the ground, which enables easy access to the components when they arrive at the factory from the component warehouse HF-200. Furthermore, since the space inside the E-factory will become more and more limited as the factory's production increases (P17). The factory should therefore be extended in order to enable a storage zone for the components when they arrive to the E-factory (see Figure 6.5). This will in turn generate more space inside of the E-factory which could be used for production since the storage zone will no longer be required to contain as many components as previously needed.

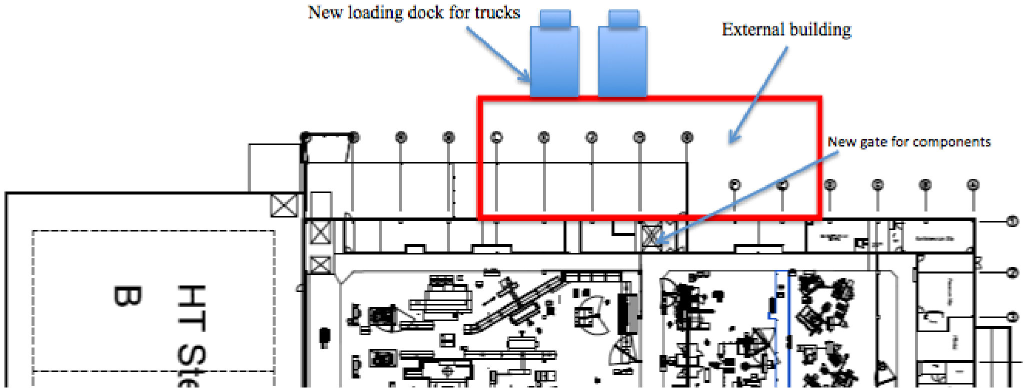


Figure 6.5: New external intermediate storage area, Source: SKF (modified)

Furthermore, placing a new gate in the middle of the factory will create a more smooth flow of components due to the more central location of the gate from the "new" storage zone outside the E-factory. In addition, the new external building will keep the components free from rain and snow which will prevent the E-factory from getting wet and dirty. Moreover, since the trucks are leveled with the factory floor the time it takes to offload the trucks containing components will decrease substantially. This will enable SLS to focus more on their core duties such as transporting material and components to and from the channels.

In order to avoid the same problem with a wet and dirty factory in the opposite side of the E-factory (P13) a porch roof should be built on top of the gate were the bearings from K30 and export products from the E-heat treatment are moved through (see Figure 6.6).

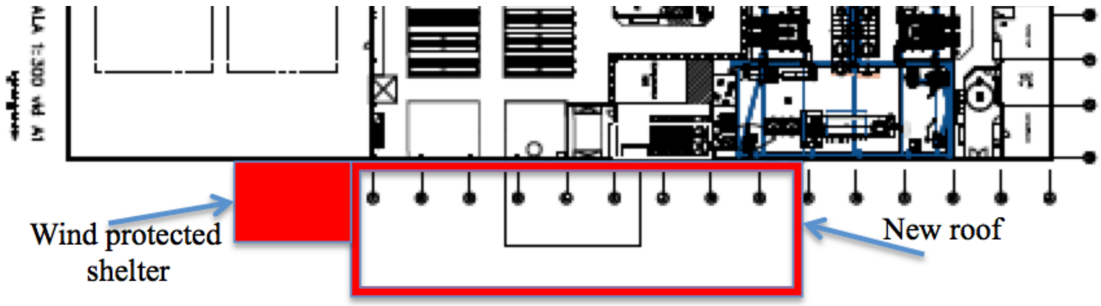


Figure 6.6: Porch roof, Source: SKF (modified)

This roof will not eliminate the problem with a wet and dirty factory but it will be reduced since the trucks will be able to off or on load the pallets and place them under protection from the roof. However, considerations regarding the size and height of the roof must be taken, since there are constraints such as limited area between the E-factory and the fence that encapsulate the entire area at SKF, which is used as on and off loading point. The optimal choice would be that the trucks are able to pass under the roof in order to avoid any accidents and not limit the area to certain sizes of vehicles. Moreover, if the roof is big enough the bearings up to 4500kg processed in K30 can, depended on weather condition, be placed just outside under the new roof with the help of their rider pallet truck if the current surface outside the gate allows this movement for this equipment. Another alternative would be to build some form of wind protected shelter to store finished products in the right or left side of the porch roof. This will free more space inside K30 and make more room for components.

E-Heat Treatment

Regarding the problem with a wet and dirty facility in the E-heat treatment (P13) the current state in the E-heat treatment there are several projects in progress. First, outside the E-heat treatments long side there is a porch roof under construction in order to prevent rings and equipment from getting wet by rain and snow (see Figure 6.7). Moreover on the short side of the E-heat treatment facility there is also a roof under construction in order to protect the rings and equipment from getting wet and dirty (see Figure 6.7). This side of the factory will be used to take in the large rings, which will be processed and hardened in Heaton 4 from 2012. Moreover, factory management has decided to postpone the building of Heaton 3 until the earliest 2013 or 2014. However, when Heaton 3 will be constructed all roller conveyers from the E-heat treatment will be moved to Heaton 4 (see Figure 6.7).

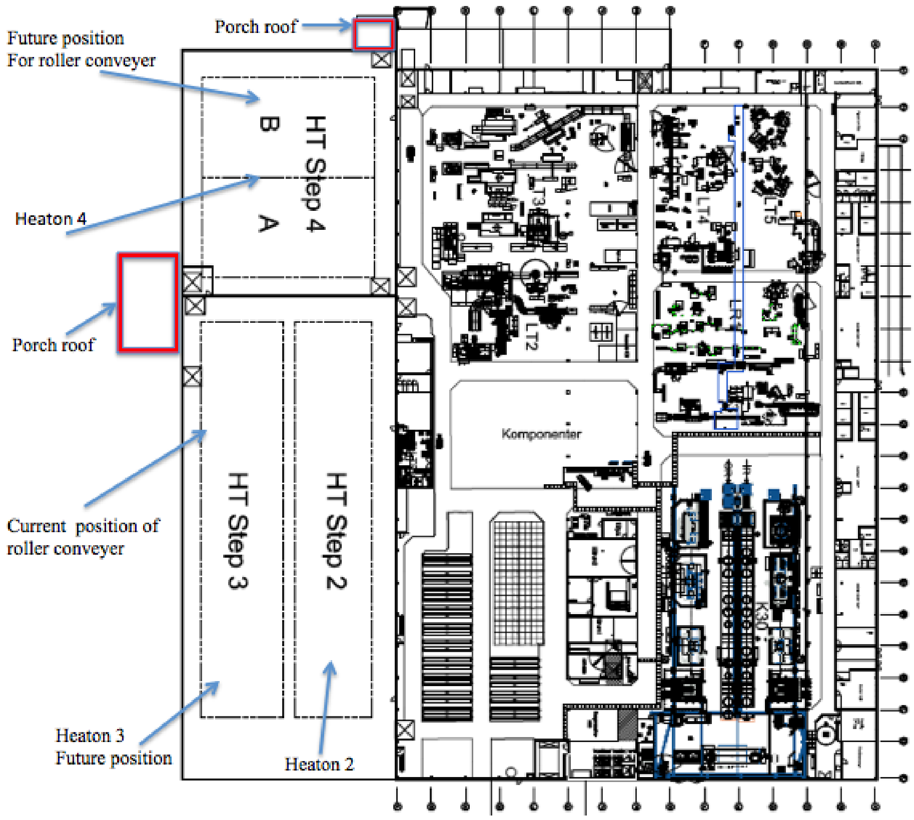


Figure 6.7: Layout E-heat treatment, Source: SKF (modified)

An alternative to the current loading areas used in relation to the E-heat treatment facility is to focused on using the benefits of having a loading dock that is lowered into the ground but instead of just being able to offload the product from the short side of the truck this alternative enables the truck to also be offloaded on the long side (see Figure 6.8). A problem with this layout is that depending on length of the vehicles/trailers carrying the rings the loading dock must be made extensively long in order for the vehicles to be leveled with the ground. This can in turn create additional problems for the surrounding traffic and environment around the E-factory and the E-heat treatment which should be carefully evaluated.

Table 6.25: Possible improvements environment fitness analysis clean factory E-heat treatment

Problem	*Possible Improvement*
P13: Wet and dirty factory	S14: Loading dock OR S15: Porch roof with wind protected shelter

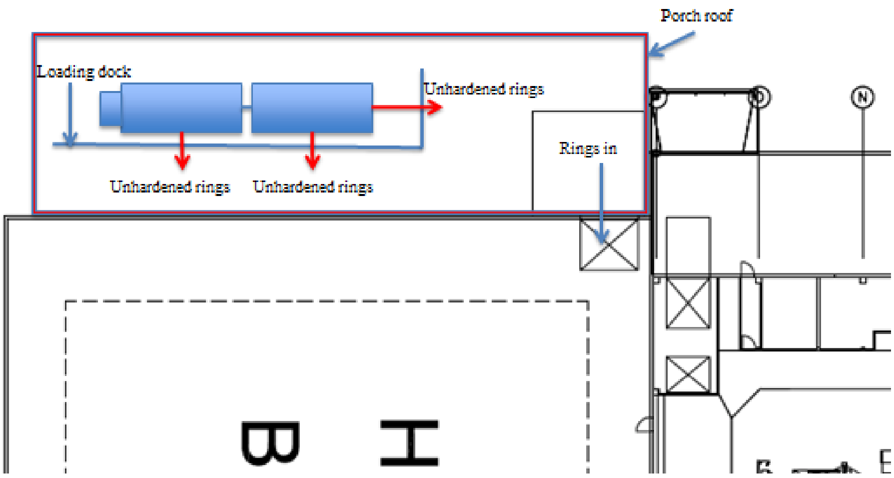


Figure 6.8: Docking bay E-heat treatment, Source: SKF (modified)

6.4.1.4 Buffer Zone E-heat Treatment

Regarding the buffers and finished rings inside the E-heat treatment all the rings that are to be processed are taken from the roller conveyers to the storage area before processing where the pallets are unpacked and made ready before entering the heat treatment (see Figure 6.9).

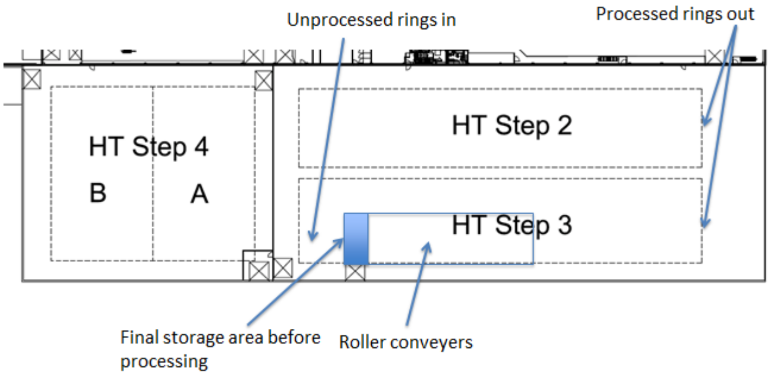


Figure 6.9: Buffer zones E-heat treatment, Source: SKF (modified)

After the rings have been hardened they are transported to the roller conveyers inside the E-factory. The rings that are going to be exported and the ones that are to be transported to channel K77 in D-factory have currently no clear buffer zone and the E-heat treatment has no place to store them before transport (P18). Depending on the amount of pallets that can be stacked on top of each other the area presented in Figure 6.10 might be adequate and should therefore be tested and evaluated.

Table 6.26: Possible improvements environment fitness analysis buffer zone E-heat treatment

Problem	*Possible Improvement*
P18: Not assigned zones for E-heat treatment buffers (Export and K77)	S9: Organize and structure buffer zones

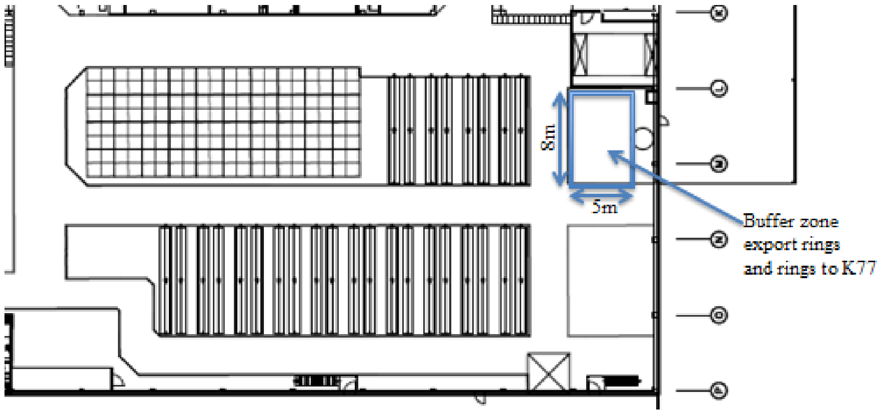


Figure 6.10: Buffer zone export rings, Source; SKF (modified)

6.4.1.5 Intermediate Component Storage Area

The intermediate component storage area is going to be used for holding components, consumables, returned products and finished products for the channels LT5, LT4, LT3, LT2, LR1 and CARB. Channel K30 will receive all its components directly to their internal storage zone where they will also store their finished products. Looking at the target layout of the E-factory, the intermediate component storage area is currently unstructured (P16) and needs to be organized in order for the area to be sufficiently utilized.

Table 6.27: Possible improvements environment fitness analysis intermediate component storage

Problem	*Possible Improvement*
P16: Unstructured "new" intermediate component storage	S16: Organize new intermediate component storage (see Figure 6.11)

In order to use the intermediate component storage area as efficiently as possible it is suggested that the area (36x20m) to be split in half in order to promote easy access for SLS when placing material in the area and when collecting material that will be distributed to the channels (see Figure 6.11). Furthermore, in order to structure the area as much as possible the intermediate component storage should be divided in to separate areas here called roller conveyors, A1, A2, A3, A4 A5 and A6 (see Figure 6.11) ,which are described in the following sections.

CARB will receive their components and rings directly to their buffer zone (A2), which is located within the intermediate component storage area close to the beginning of CARB (see Figure 6.11). The reason for this is that CARB needs a buffer zone to store rings that have been processed and are waiting for the inner or outer ring before assembly. Hence, to reduce pallet movements the intermediate component storage area for CARB should be able to cope with a 24-hour buffer of components and an intermediate storage for rings.

Roller Conveyers

In order to use the area for incoming components suitably a scenario would be to use roller conveyers to place rollers, cages, sleeves and guide rings in. However, since the batch sizes varies in terms of number of pallets, which is depending on size of the bearings that are produced it is hard to determine how much space each channel need for their different components in the roller conveyer. According to Lumsden (2006), if adjusting handling equipment to peaks in demand it will result in low usage of equipment. Hence, a proper balance is needed to be found. If dividing the upper half (36x10m) of the intermediate component storage into two parts (18x10m) and placing ten, two-story roller conveyers in this area it would take up a total of 180m^2 of the total 360m^2. Each of the lanes in the roller conveyer is capable of holding 16 half-pallets. The roller conveyers should be used to store rollers, cages, sleeves and guide rings pending on size of the unit loads. The total amount of rollers on half-pallets that are demanded to be stored on the roller conveyers according to the forecast 2015 (see Table 6.28) figures provided by the supply chain department are 127. Therefore, the rollers will demand four of the ten two-story roller will be (16x4x2=128 half-pallets) in order to be able to cope with the demand.

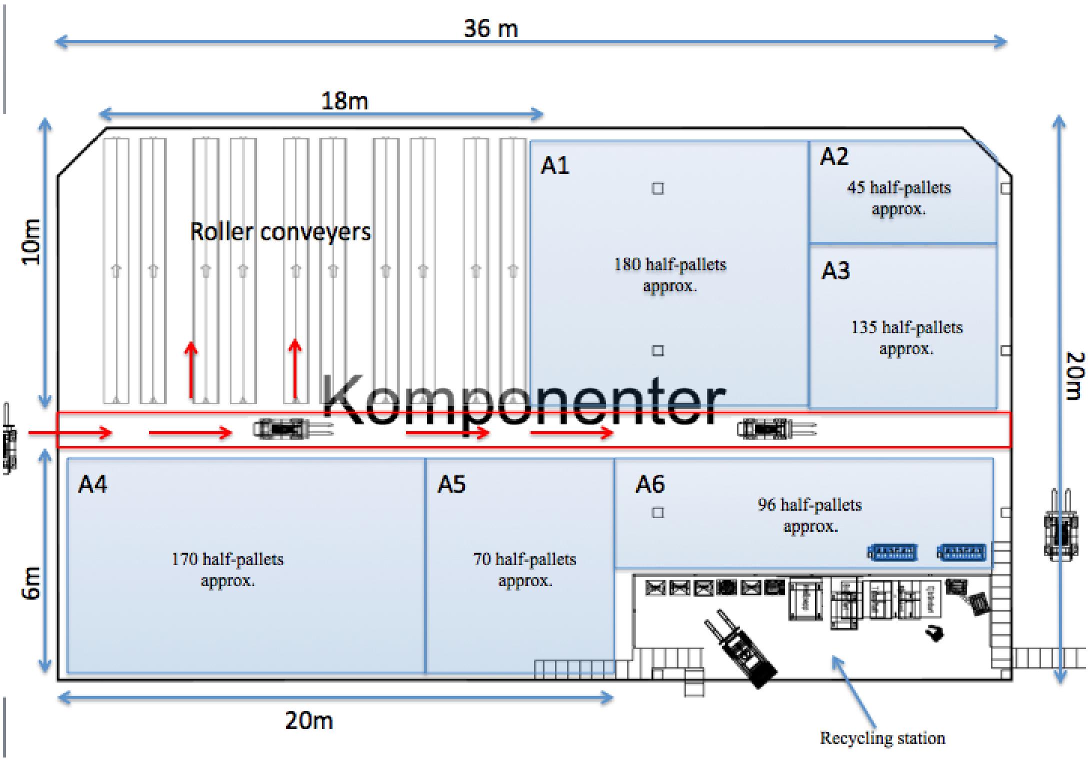


Figure 6.11: Intermediate component storage, Source: SKF (modified)

Regarding the remaining six of the ten two-story roller conveyers, which will be used to store cages, sleeves and guide rings from LT5, LT4, LT3, LT2 and LR1 the storage capacity here will be 192 half-pallets. The demand 2015 according to E-factory supply chain will be (94+61) 154 half-pallets including the oversized wooden crates, which cannot be stored on roller conveyers. Hence, the six two-story roller conveyers will provide sufficient storage for these components. However, a problem can occur if each of the channels components should not be mixed in the same roller conveyer lanes. In order to solve this problem an additional story could be added to the lanes which will generate even more space for the components.

Table 6.28: 24-hour area demand, Source: SKF

24-hour buffer area demand 2015(half-pallets)	
Roller	127
Sleeves/Guiderings	61
Cages	94
Wooden crates	149
Finished products	155

A1

Empty wooden crates and oversized wooden crates containing cages and guide rings belonging to bearings that are produced in LT3 and LT2 are suggested to have a buffer zone next to the roller conveyers. This area will approximately be able to handle 180 half-pallets. The number provided by supply chain shows that the area demanded for wooden crates 2015 will be 149 half-pallets. In addition, the cages that cannot be stored in the roller conveyers need to be stored in this area as well. Moreover, the fact that some of the empty crates can be stored on top of each other has not been taken into consideration. Hence, the number of half-pallets that can be placed in A1 should be sufficient.

A2

This area in intermediate component storage consists of the total number of components and rings that will be needed in CARB for a 24-hour buffer. Supply chain has provided these figures (see Table 6.29) which shows that the current demand for components and rings will be 33 half-pallets for 2015. Therefore, to secure that A2 will be able to cope with fluctuation in demand it is suggest that the area should be able to cope with at least 45 half-pallets.

Table 6.29: 24-hour area demand CARB, Source: SKF

24-hour buffer zone demand 2015 (half-pallets) for CARB	
Roller	6
Cages	7
Wooden crates	5
Rings	15
Total	33

A3

This area will be used to store processed white rings from LT3 and LT2. As of now nobody knows the exact need of space for the white rings. The largest white ring transported on shackles takes approx. up an area of 1.4m^2. A3 consists of an area that can hold 135 half-pallets, which is approx. 70m^2. This will impose that (70/14= 50) 50 of the largest shackles containing white rings from LT3 and LT2 will be able to be stored in area A3.

A4

The area A4 should be used to store finished products from LT5, LT4, LT3, LT2, LR1 and CARB. The 24 hour buffer area for finished products for 2015 is estimated by supply chain to be 155 half-pallets (see Table 6.28). The total area of A4 can hold approx. 170 half-pallets. Hence, there is a clear sufficient amount of area to store finished products in even after the increased demand in 2015.

A5

This area should be used to store returned products such as, rings, cages and rollers from the different channels. No clear figures exists for returned products, therefore it is suggested that the area should start by holding approx. 70 half-pallets. If the space is not sufficient it will most probably be possible to borrow space from area A6 if there is a need for this.

A6

This area will be able to contain 96 half-pallets and due to its placement behind the recycling station it is suitable to use for storing empty cardboard boxes, fluids, consumables, etc. In addition, it can be used as an extra storage area for the components if the buffer zones in some of the other areas are insufficient.

6.4.2 Channel Environment Fitness Analysis

6.4.2.1 LT5

Beginning of LT5

In the current situation at the beginning of LT5 all the inner and outer rings are delivered to the internal buffer zone that is shared with LT4. Usually the area is filled as much as possible with rings. The area for LT5 is capable of handling 4x2 EUR-pallets with rings (see Figure 6.12).

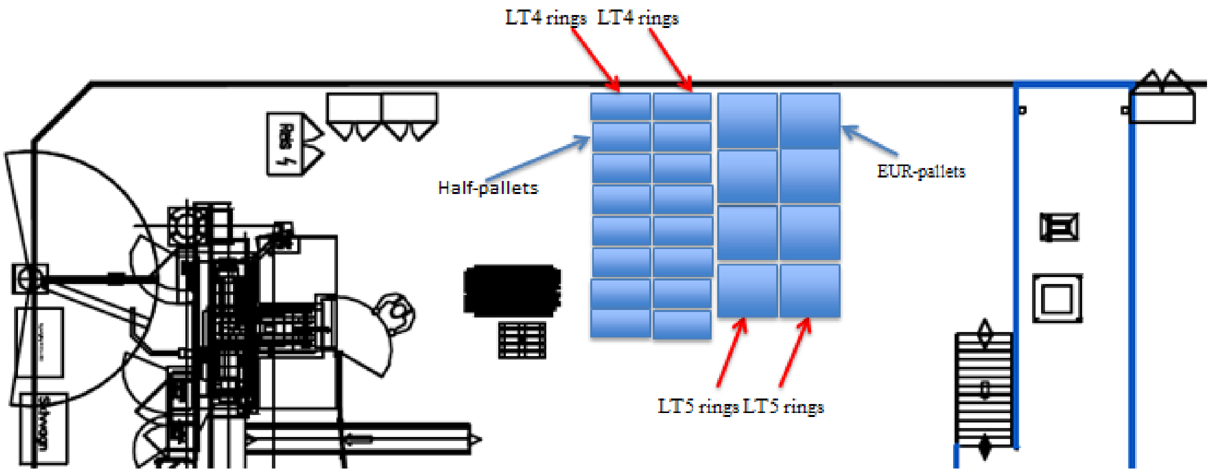


Figure 6.12: Beginning LT5/LT4, Source: SKF (modified)

When implementing WASS (P20) to the E-factory the channel will be able to cope with a maximum of 4 half-pallets of inner and outer rings (see Figure 6.13). When a pallet is scanned, WASS will send a signal to SLS regarding the remaining quantity. Since there is a certain time window for the supply of new rings, SLS has to deliver rings to LT5 within this specific time period in order to avoid running out of rings.

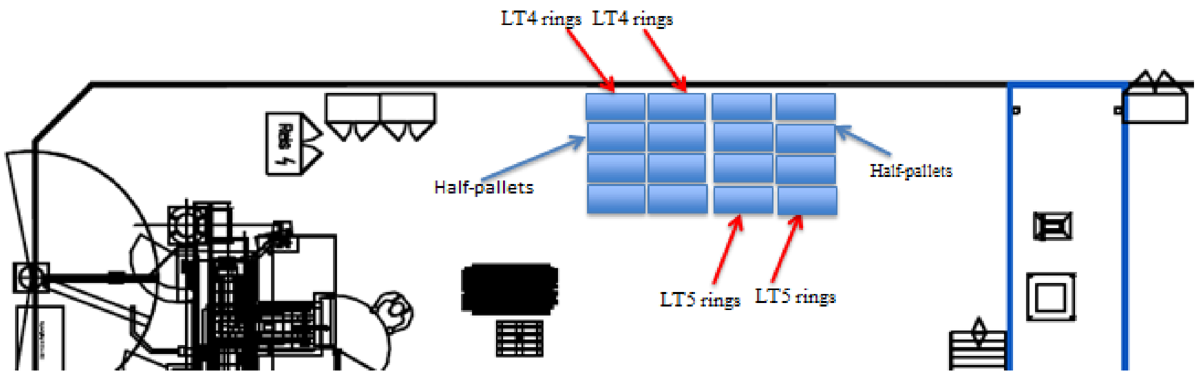


Figure 6.13: New layout beginning LT5/LT4. Source: SKF (modified)

End of LT5

In the end of LT5 the buffer space for components, consumables and finished products are situated according to Figure 6.14. The current layout of the end of LT5 provides easy access for the channels operators in terms of components and consumables. However, in order to successfully implement WASS (P20) in LT5 the scissor table in the end of the channel needs to be moved or replaced with a smaller one in order for SLS to deliver and collect finished products and components with the use of a forklift truck or similar (P12).

Moreover, since the central-warehouse (CL) which handles all finished bearings has problems in handling EUR-pallets (P1), an alternative would be to shift from placing finished products on EUR-pallets to half-pallets for finished bearings. This would create a situation where the use of a scissor table for half-pallets is made possible in the end of LT5 (see Figure 6.15). The size and alternative placement of the scissor table in the new layout will eliminate the constraints.

Since EUR-pallets are not needed within LT5 anymore a new location for storing finished products will be created and replace the storing of empty load carriers. This location will promote easy access for SLS and reduce the need of collecting finished bearings inside the channel. However, LR1 also uses this area to store their empty EUR-pallets that have been used to carry empty blue plastic boxes. The part about LR1 in this section will provide an alternative to this situation.

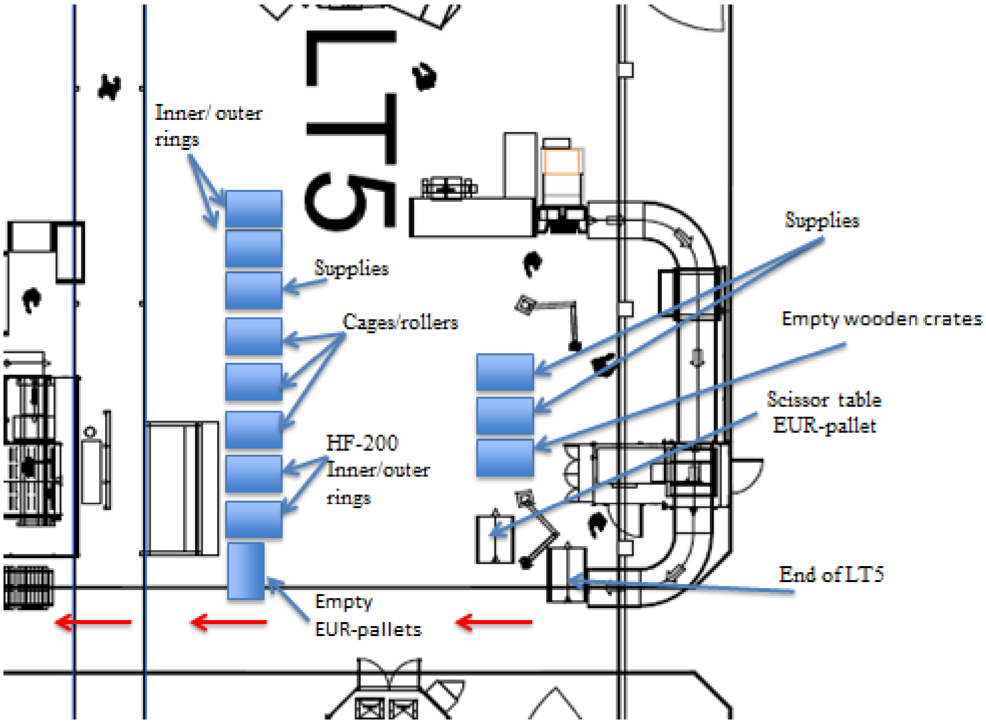


Figure 6.14: End of channel LT5, Source: SKF (modified)

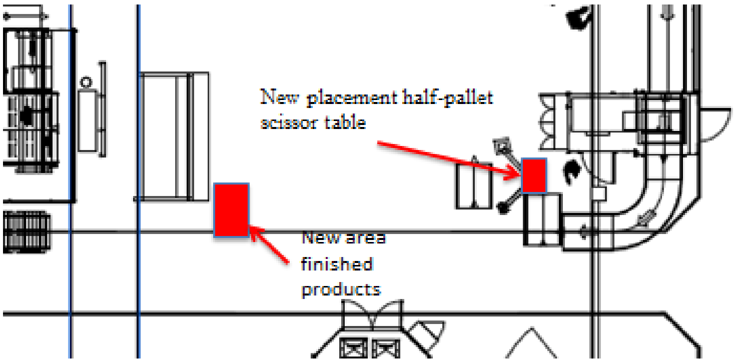


Figure 6.15: New layout end of channel LT5, Source: SKF (modified)

Table 6.30: Possible improvements environment fitness analysis LT5

Problem	*Possible Improvement*
P20: Buffers not adapted to WASS or SLS handling	S9: Organize and structure buffer zones (see Figure 6.13 and 6.15)
P12: Limited turning space	S11: Reconstruct aisle between LT5 and LR1
P1: Central storage cannot handle EUR-pallets	S1: Rings and finished bearings on half-pallets

6.4.2.2 LT4

Beginning of LT4

In the current situation at the beginning of LT4 all the inner and outer rings are delivered to the internal buffer zone that is shared with LT5. Usually the area is filled as much as possible with rings. The area for LT4 is capable of handling 8x2 half-pallets of rings (see Figure 6.12). It is suggested that when implementing WASS (P20) to the E-factory LT4 will be able to cope with a maximum of 4x2 half-pallets of inner and outer rings (see Figure 6.13).

End of LT4

In the end of LT4 there is currently space allocated for storage of components and empty cardboard boxes right next to the main aisle between LT4 and LT3 (see Figure 6.16). Moreover, the white rings and leftover cages are stored even more closely to the assembly area (see Figure 6.16). This area contains a racking, where the white rings are placed in. In front of the racking the leftover cages and rollers waiting to be transported back to HF-200 are stored, this area has the size of six EUR-pallets. Moreover, empty load carriers are placed on the right side of the racket.

In order to enable the incoming components to be placed more closely to the assembly area in LT4 and thereby reduce the time for transporting material from the internal buffer zone to the assembly area (P2), leftover cages should be transported to HF-200 instead of being stored in the channel or be stored where the incoming components are placed currently. This will generate storage for incoming components in front of the racking containing white rings. Furthermore, this will also shorten the distance the SLS operators need to transport the components from the intermediate component storage to LT4 (see Figure 6.17).

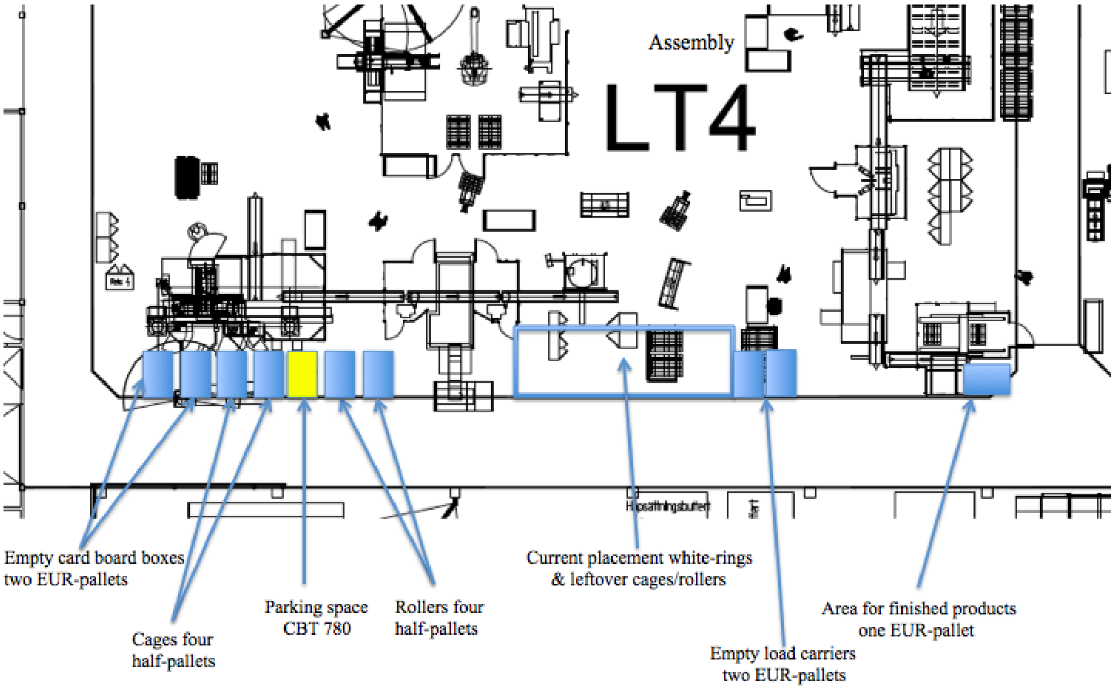


Figure 6.16: End of channel LT4, Source: SKF (modified)

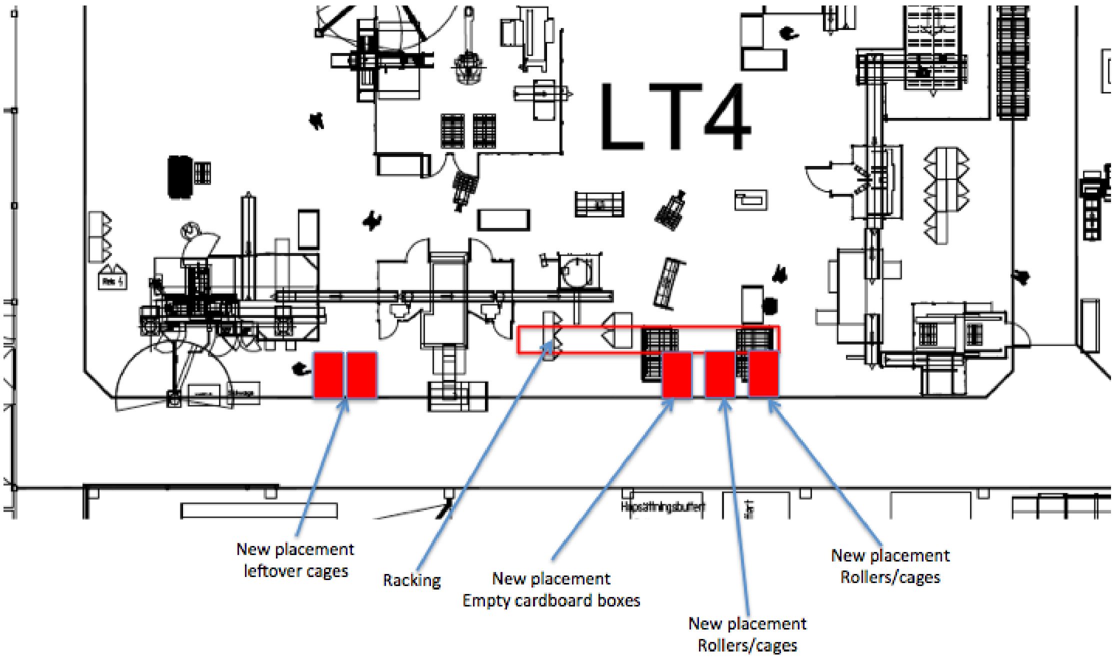


Figure 6.17: New layout end of channel LT4, Source: SKF (modified)

When implementing WASS in LT4 there will only be demand for two half-pallets per component since when a half-pallet is scanned it will send a signal to SLS that there need to deliver a new half-pallet (P20). Regarding the EUR-pallets containing the packaging material, the cardboard boxes should be transported on half-pallets instead of EUR-pallets in order to avoid the use of EUR-pallets in LT4since these can be reused in the end of the channel (P3).

Table 6.31: Possible improvements environment fitness analysis LT4

Problem	*Possible Improvement*
P20: Buffers not adapted to WASS or SLS handling	S9: Organize and structure buffer zones (see Figure 6.13 and 6.17)
P2: Long distance to intermediate component storage	S9: Organize and structure buffer zones (see Figure 6.17)
P3: Not reusing load carriers within channel	S1: Packaging material on half-pallets

6.4.2.3 LT3

Beginning of LT3

In the beginning of LT3 the current situation is presented in Figure 6.18. The rings are stored in the intermediate area to the beginning of the channel. Furthermore, the rings that due to poor quality or similar are not capable of being processes are placed in the same area on the left side of LT3. The empty load carries from the rings are placed near the left scissor table.

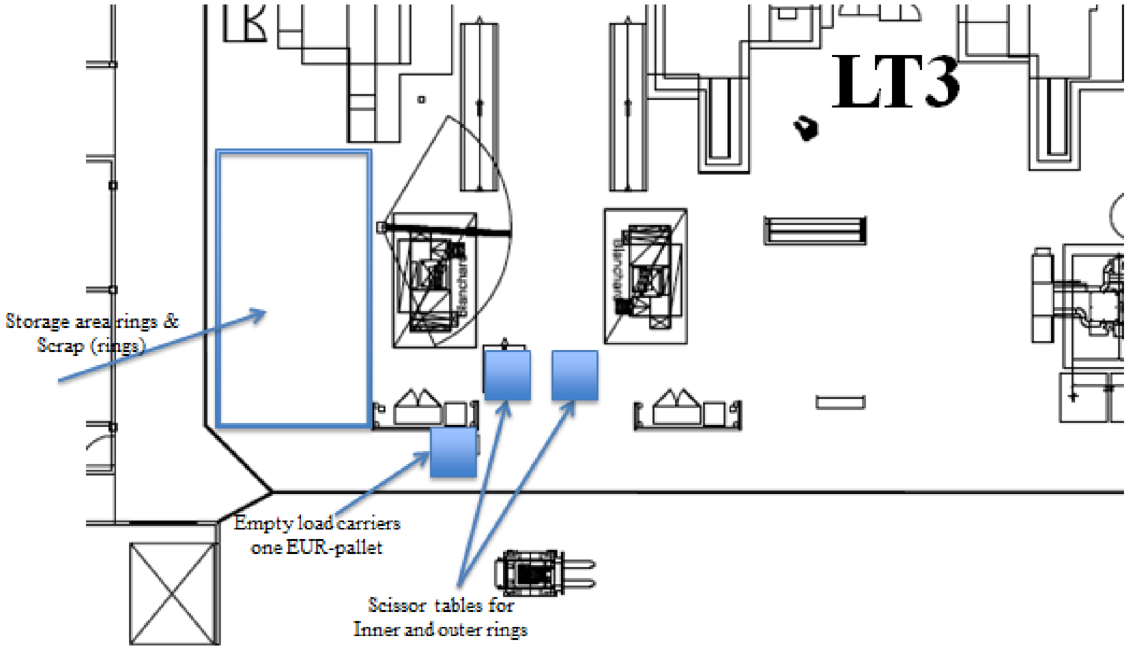


Figure 6.18: Beginning of channel LT3, Source: SKF (modified)

As an alternative to the current layout in the beginning of LT3 instead of having scissor-tables the channel (P6) could have roller conveyers that can hold three EUR-pallets each, which the rings are placed directly on when they are delivered from SLS instead of being stored in the intermediate internal buffer zone (see Figure 6.19). This would create a scenario where the pallets movements are limited and the internal buffer zone for rings can be reduced and used for better purposes.

Moreover, when implementing WASS into LT3 the need for 2x2 EUR-pallets for inner and outer rings on the roller conveyer is sufficient (P20). When one pallet is scanned the signal is sent to SLS and they are given the task to deliver a new pallet containing either inner or outer rings. The area containing scrap can remain the same as well as the placement of the empty load carriers.

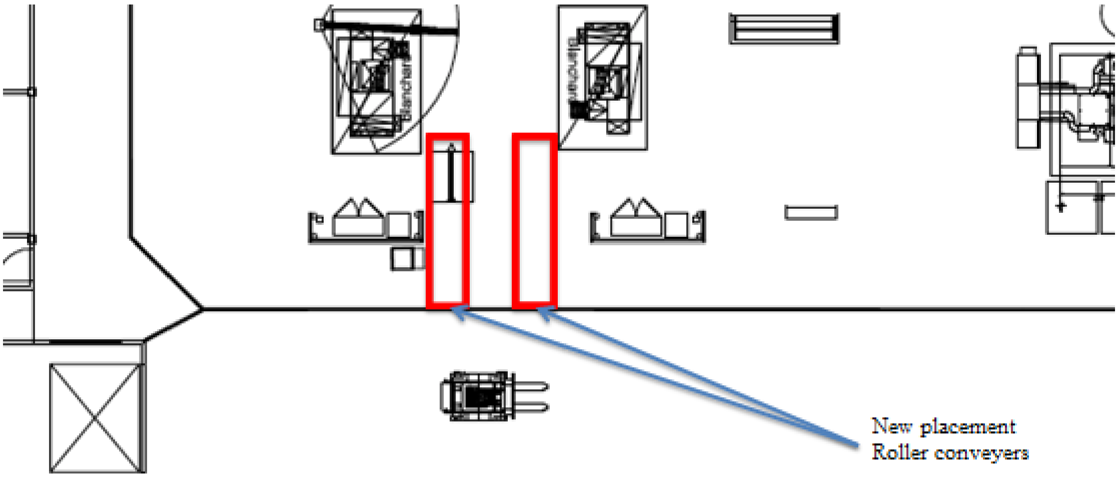


Figure 6.19: New layout beginning of channel LT3, Source: SKF (modified)

End of LT3

In the end of LT3 the current situation is presented in Figure 6.20. The area for the components is currently not divided into separate zones for each component (P20). Regarding the finished products, the bearings are lifted by a traverse on to the scissor table containing the empty wooden crate that will store the finished bearing. From this point the finished bearing is transported to the intermediate component storage. The internal buffer zone for components and white rings should get an alternative layout which is presented in Figure 6.21.

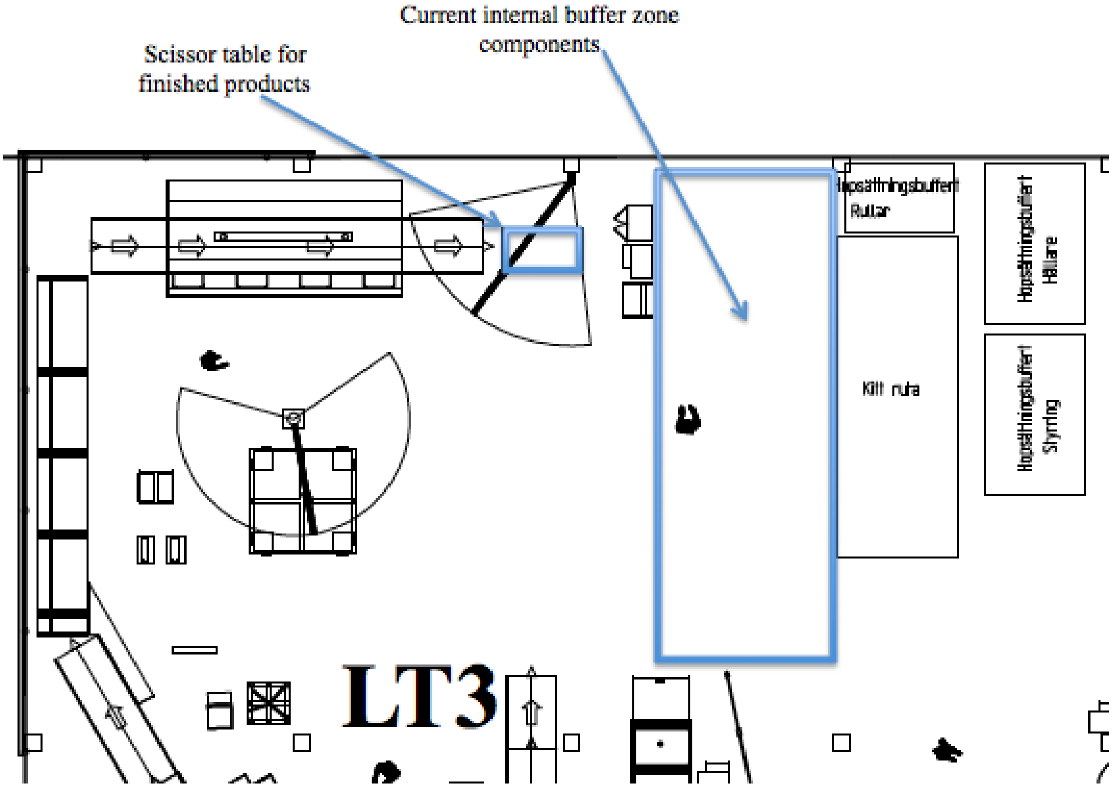


Figure 6.20: End of channel LT3, Source: SKF (modified)

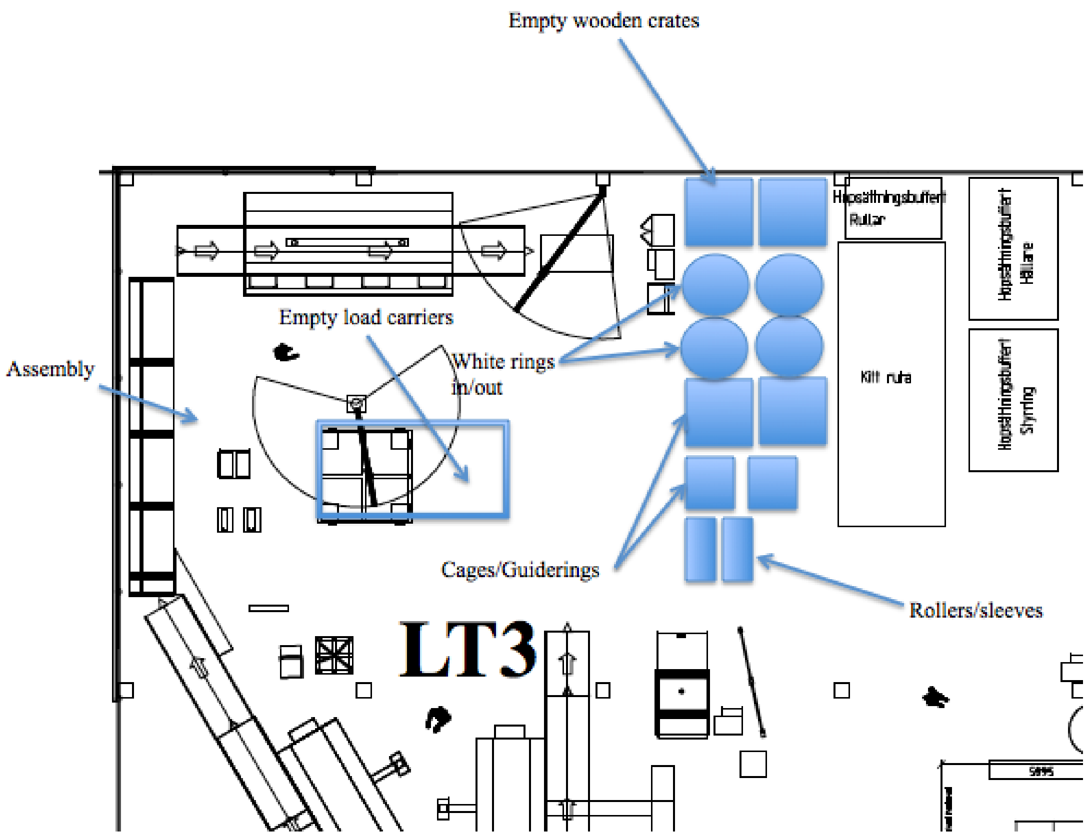


Figure 6.21: New layout end of channel LT3, Source: SKF (modified)

Here the layout will be structured according to the constraints set by WASS, where two unit loads per component is stored in the internal buffer zone in order to avoid excess storage of material. Regarding finished bearings the scissor table in the end of the channel provides only sufficient storage when SLS collected the bearing within the short time window of approximately 20 min. Finally, the empty load carrier (P9) could be place according to the Figure 6.21. This will enable the SLS operators to collect the empty load carriers.

Table 6.32: Possible improvements environment fitness analysis LT3

Problem	*Possible Improvement*
P6: Move each pallet separately into first machine	S8: Roller conveyer before first machine (see Figure 6.19)
P20: Buffers not adapted to WASS or SLS handling	S9: Organize and structure buffer zones (see Figure 6.21)
P9: No assigned buffer zones for returned parts and load carriers inside channel	S9: Organize and structure buffer zones, assign routines

6.4.2.4 LT2

The present situation in the beginning of LT2 is that the channel is under construction. As of now, only inner rings are processed. The current buffer zone for the inner rings is presented in Figure 6.22. Moreover, this figure also displays how LT2 will be structured when it is completed in 2013. However, when LT2 is complete the inner and outer rings will be processed in the “new placement LT2” (see Figure 6.22) and not were the inner rings are presently being processed (current beginning LT2). This line will instead be used for the largest rings in LT3.

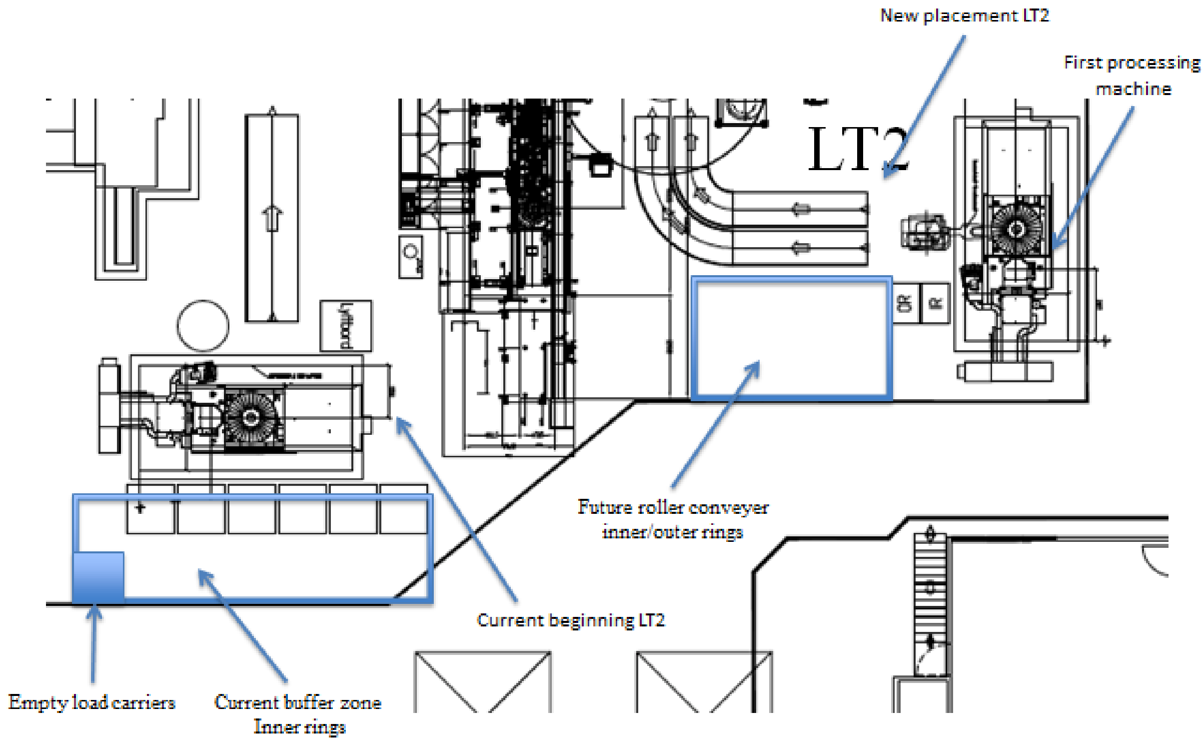


Figure 6.22: Beginning of channel LT2, Source: SKF (modified)

Beginning of LT2

When analyzing the current layout and the target layout it can be proposed that in order to create a well function workstation for the channel operators that are adapted to meet the demands set by WASS (P20), the use of roller conveyers (P6) would be an appropriate choice in the new placement of LT2 since it is frequently used for storage of material before assembly or processing. In addition, the pallet movement will also be limited if using a roller conveyer in these two areas. The size and shape of the roller conveyer should be determined when the channel is up and running. However, considering the constraints set by WASS the conveyer need not be able to carry more than two or three pallets since SLS will be able to feed the channel with rings when needed.

End of LT2

In the present state, the area in the end of LT2 has no processing machines in place therefore it is difficult to give a direct answer without seeing the final solution. When looking at the target layout of the end of LT2 (see Figure 6.23) the buffer zone for components are presented in the upper right corner. In addition, the processed rings are stored in the near the end of the component buffer zone. When observing and analyzing this area it cannot be found any alternative solutions. The buffer zone for finished products should be located near the intermediate component storage in the E-factory in order to minimize transportation for SLS. Moreover, the buffer zone for finished products in LT2 should be capable to store a minimum of two EUR-pallets of finished bearings in order to cope with the demands and constraints set by the implementation of WASS. This area should also be able to handle empty load carriers from the components. The location of the load carries should be easy for the SLS operators to access.

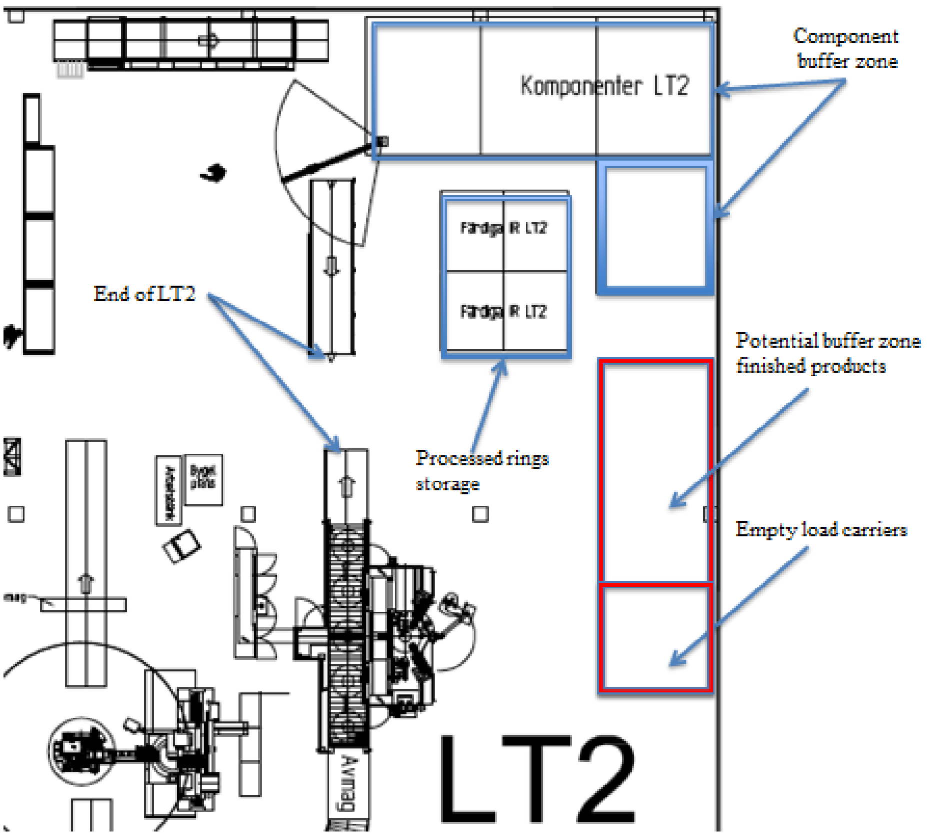


Figure 6.23: End of channel LT2, Source: SKF (modified)

Table 6.33: Possible improvements environment fitness analysis LT2

Problem	*Possible Improvement*
P20: Buffers not adapted to WASS or SLS handling	S9: Organize and structure buffer zones (see Figure 6.22 and 6.23)
P6: Move each pallet separately into first machine	S8: Roller conveyer before first machine (see Figure 6.22)

6.4.2.5 CARB

When analyzing the current layout of CARB the existing arrangement is structured like shown in Figure 6.24.

Beginning of CARB

CARB receives all its rings to the intermediate component storage located next to the channel by SLS. The rings are then placed on the two roller conveyers by the channel operators. Since the channel only is capable of processing one type of ring (inner or outer) at a time the rings that are processed need to be placed next to the channel until the other ring has been processed. This creates a demand for a rather large buffer zone for components and rings.

An alternative in the beginning of CARB would be to have SLS placing the rings directly on to the roller conveyers when WASS has been implemented (P20). When a half-pallet has been scanned by the channel operators SLS receives a signal that they must deliver a new pallet within the respective time window.

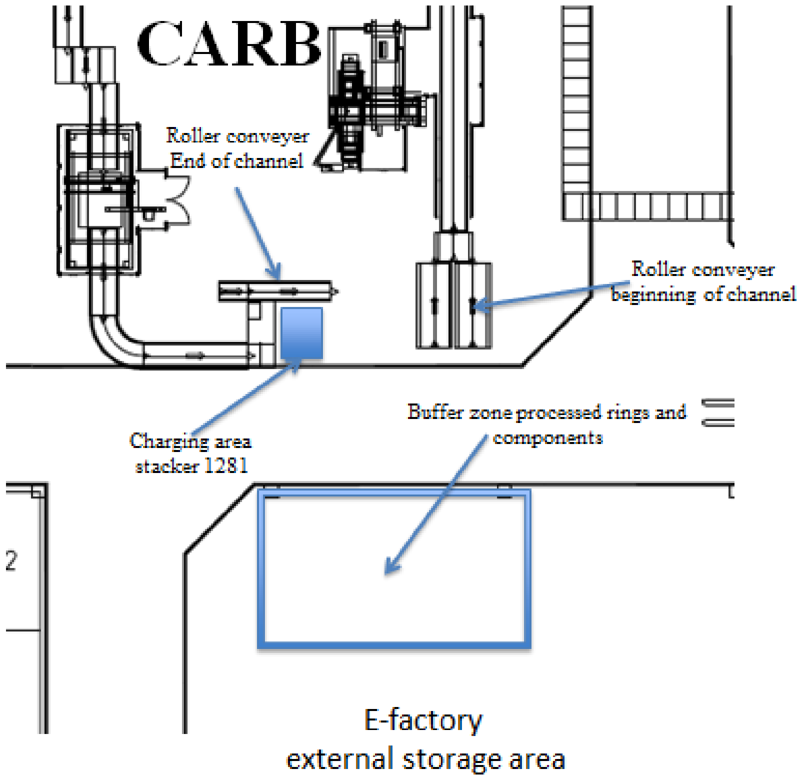


Figure 6.24: Beginning of channel CARB, Source: SKF (modified)

End of CARB

The end of CARB is currently comprised of a roller conveyer to put on half-pallets containing finished bearings. The roller conveyer is capable of carrying a maximum of three half-pallets. Furthermore, the charging area of the stacker 1281 is situated in front of the roller conveyer. In order for SLS to be able to collect the finished products from CARB and transport them to the intermediate component storage the charging area of 1281 needs to be moved in order to enable this process. Finally, the time window in CARB is approximately one hour when the channel performs packaging work. Therefore, the amount of half-pallets stored on the roller conveyer pose no problems for the implementation of WASS.

Table 6.34: Possible improvements environment fitness analysis CARB

Problem	*Possible Improvement*
P20: Buffers not adapted to WASS or SLS handling	S3: SLS more tasks, operates 24/7 and later WASS

6.4.2.6 K30

Beginning of K30

In the present situation in the beginning of K30 the channel is waiting for the removal of channel CR3, which will enable turning point and accessibility for SLS when they are transporting inner and outer rings to the beginning of K30. Due to the long time window of about four hours in K30 there is no need for more than two rings at a time in the beginning of the channel. Furthermore, the placing of the oversized blue pallets appears correct for the target layout (see Figure 6.25). Therefore the target layout of K30 should remain the same with no alteration in this analysis.

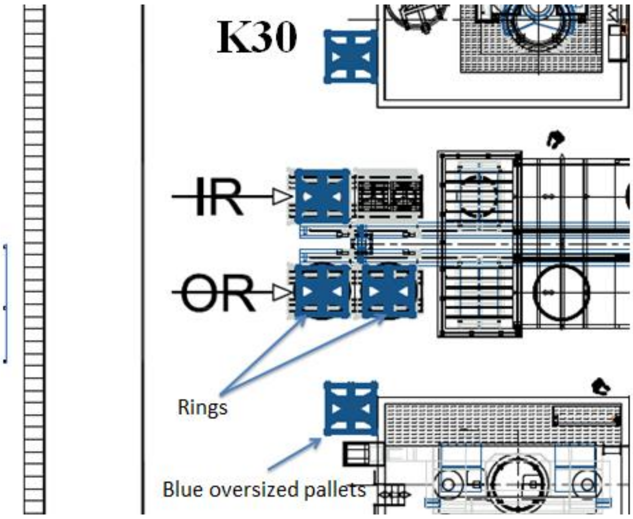


Figure 6.25: Beginning of channel K30, Source: SKF (modified)

End of K30

The buffer zone for components and finished products (P20) in K30 must be able to cope with the demand set by the 36-hour buffer demand that is given by the supply chain manager of K30 (see Table 6.35).

Table 6.35: 36-hour buffer area demand K30, Source: SKF

36-hour buffer zone demand 2015 (half-pallets) in K30	
Roller	6
Guiderings/Sleeves	6
Cages	12
Wooden crates	24
Finshed products	24

The number of bearings produced in K30 during this time period ranges from 5-6 bearings (24 half-pallets). The time window for SLS to pick up and collect the finished bearings in K30 is between 5-6 hour therefore no more than two complete bearings needs to be stored in the channel simultaneously. Having the total number of bearings produced in mind the need for empty oversized wooden crates during this time period will be the same as finished bearings, 5-6 (24 half-pallets), which can be stacked on top of each other in order to reduce space in the buffer zone. The rollers demand an area of 6 half-pallets in the same time period. Furthermore, the cages require an area of 12 half-pallets or space for 5-6 oversized wooden crates in order to cope with the demand of a 36-hour buffer. The sleeves and guide rings also demand a space of 6 half-pallets.

Regarding the empty load carriers (P9) that are collected by SLS in K30, it is suggest that they should be placed in close proximity to the finished bearings in order to promote visual surveillance for the SLS operators, enabling easy detection on when to collect them. Moreover, this specific area can be shared with storage of cages pending on number of cages stored and stacked on top of each other. Taking these aspects into consideration an alternative layout regarding the components in the end of K30 should be arranged according to Figure 6.26.

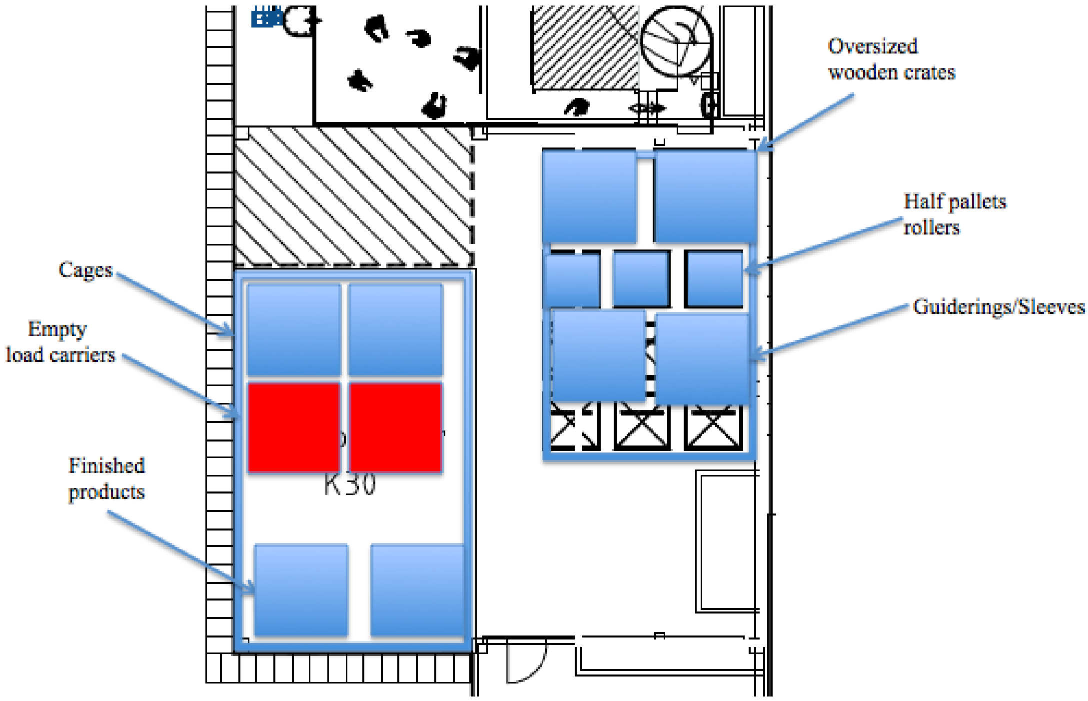


Figure 6.26: End of channel K30, Source: SKF (modified)

Table 6.36: Possible improvements environment fitness analysis K30

Problem	*Possible Improvement*
P20: Buffers not adapted to WASS or SLS handling	S9: Organize and structure buffer zones (see Figure 6.26)
P9: No assigned buffer zones for load carriers inside channel	S9: Organize and structure buffer zones (see Figure 6.26)

6.4.2.7 LR1

Beginning of LR1

In the analysis of the beginning of channel LR1 shows that the area where the rollers are stored is structured like viewed in Figure 6.27. The layout of the internal buffer zone is currently very organized and shows exactly where all the different rollers should be placed. The only thing that could be improved is the amount of unprocessed rollers. The volume should after WASS is implemented (P20) be adjusted so that each of the four lines within LR1 does not have more than two half-pallets in the buffer zone at a time. This will eliminate any unstructured placement of rollers in the buffer zone and also make it easier for both SLS and channel operators to find the right components or rollers that are going to be processed.

End of LR1

In the end of LR1 there is a half–pallet scissor table in place, which the blue plastic boxes or half-pallets containing rollers are placed on. After one half-pallet is full the rollers are currently transported to the intermediate component storage by the channel operators (P2). The empty blue plastic boxes currently arrive on both EUR-pallets and half-pallets (P3). They are placed like it can be seen in Figure 6.28.

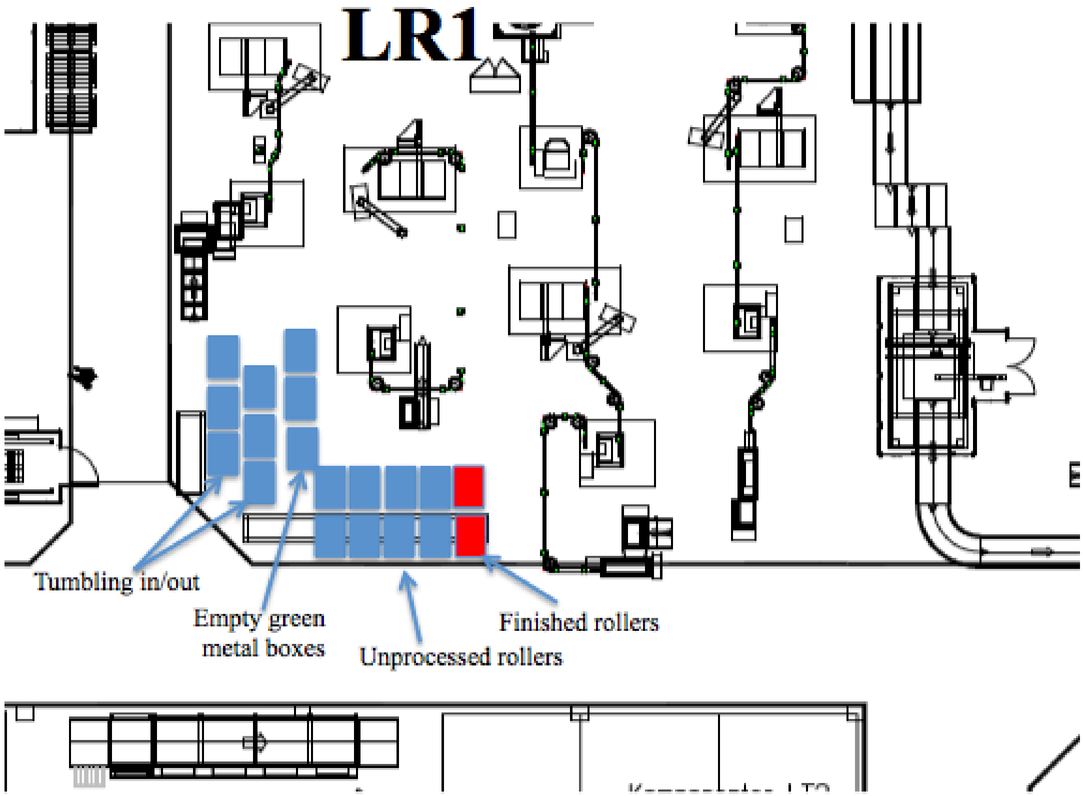


Figure 6.27: Beginning of channel LR1, Source: SKF (modified)

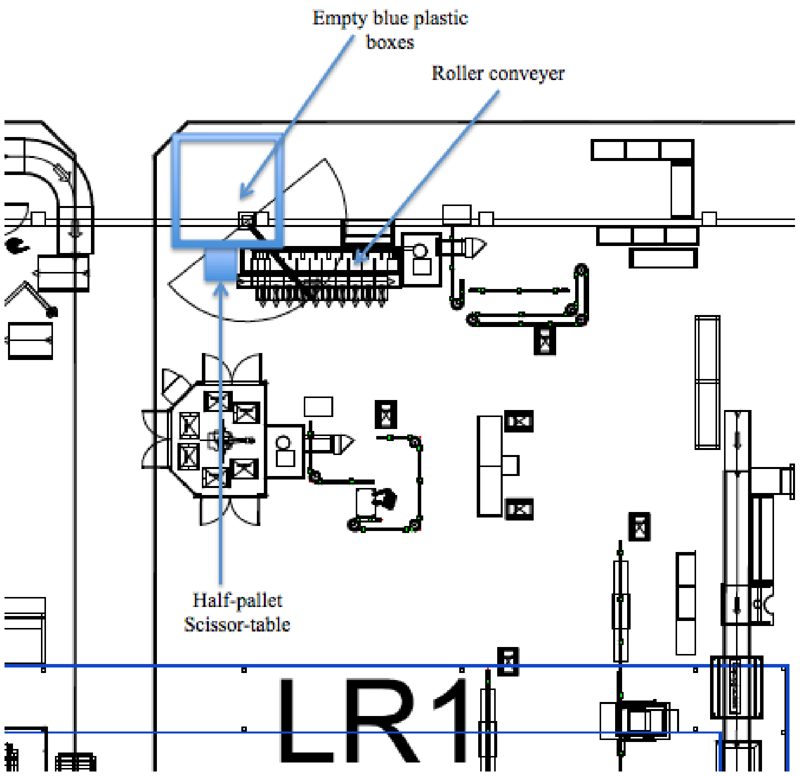


Figure 6.28: End of channel LR1, Source: SKF (modified)

During the analysis of the layout it felt that there is a large amount of empty blue plastic boxes being stored in the end of LR1. When implementing WASS in LR1 there will only be needed two half-pallets of empty blue plastic boxes in the end of LR1. Furthermore, the finished rollers can be stored right next to the scissor table waiting to be picked up by SLS with a time window of about one hour. Moreover regarding the problem with storage of EUR-pallets which was discusses in the environment fitness analysis of LT5, if eliminating the use EUR-pallets to put empty blue plastic boxes on in LR1 and changing it to only be stored on half-pallets there will be no need for this unit load in these two channels and therefore this area can be used to store finished bearings for LT5.

Another aspect to take in to consideration is the aisle between LR1 and LT5 which eliminate the possibility for SLS to collect rollers from LR1 (P11). Therefore as an alternative to changing the aisle the finished rollers could be transported from the end of the channel and transported to the internal buffer zone in the beginning of LR1 (see Figure 6.29). This will enable the SLS operators to collect the finished rollers and transport them to the intermediate component storage in the E-factory instead of the channel operators.

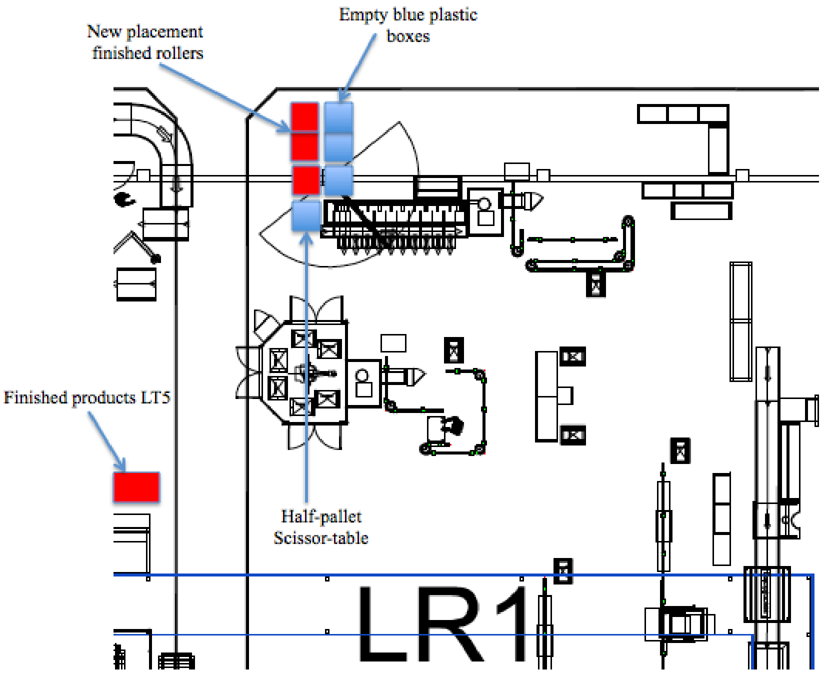


Figure 6.29: New layout end of channel LR1, Source: SKF (modified)

Table 6.37: Possible improvements environment fitness analysis LT4

Problem	*Possible Improvement*
P20: Buffers not adapted to WASS or SLS handling	S9: Organize and structure buffer zones (see Figure 6.29)
P2: Long distance to intermediate component storage	S9: Organize and structure buffer zones (see Figure 6.29)
P3: Not reusing load carriers within channel	S1: Packaging material on half-pallets
P11: Aisle between LT5 and LR1 not accessible for a forklift truck	S11: Reconstruct aisle between LT5 and LR1

6.5 Information Flow Analysis

Always when material is moved or is about to be moved, information and an information flow is generated. Today are information flows closely related to the use of IT systems which are used to generate, store and communicate information. In the theory chapter 3.5 about information systems where divided into three categories. Based on these categories the information flow in SKF's E-factory will be analyzed. Emphasis will be on the current handling of information flows, planned changes and current difficulties. One important fact in this part is to have in mind the planned implementation of the WASS system and the compatibility of information flows with the use of WASS. Therefore, it is important to find out what needs to be adapted to the features of WASS to facilitate the implementation.

6.5.1 Planning and Execution Systems

Before anything will be produce it is important to decide what should be produced. In the E-factory the major part of bearings are made to order (LT3, CARB3, K30) and for the percentage of bearings that are made to stock (LT4, LT5) sales data is used to decide about future production amounts. Based on orders and forecasted sales, a production plan i.e. sequence list is constructed which is the basis for the whole production process. Because the rings are not casted in Gothenburg and they need to be delivered to the factory area, the production process starts with ordering rings as well as rollers, cages, sleeves and guide rings which are also produced outside the E-factory in Gothenburg. Therefore the planning and execution tools are used in the first step to define what to produce and which types of components are needed from suppliers or other parts of the factory.

The supply chain department for the E-factory that is responsible for this process is located inside the factory building. Responsibilities for each of the channels are divided between the employees. To be able to construct a production sequence an integrated information system is needed and used that includes orders, sales numbers and forecasts as well as it has access to which parts are available at the warehouse and which delays need to be considered in the sequence list. The information system underlying and used for this process is MCSS, as a production planning system which is integrated in SKF's ERP system SARA. Furthermore, the channel managers have access to the planned sequence and base their process on them. The sequence list is available about one and a half month in advanced but is from time to time adapted based on information on missing components or prioritized orders. At one point in time, about one week before production start at the E-factory, the sequence list become locked and will not be changed or altered. Each channel has its own sequence list which includes information about the product type (each channel produces about 30-300 different bearing types), date of production start, amount to be produced and which parts are in stock from previously producing this type. Currently the E-heat treatment does not use this sequence list for their operations (P19) which would improve material handling significantly. Having the implementation of WASS in mind the sequence list would be the basis for the operation of WASS as well.

Another information system that is crucial for the factory is the warehouse management system that is one part of MCSS which handles in and out flow from the storage and actual stock levels. Except the importance of stock levels for planning the production planning, MCSS is important to handle material flows to and from the E-factory especially in connection to the planned WASS implementation (see Figure 6.30). In addition, this information is used to determinate delivery dates and handles the transport from the factory. Furthermore, it is important to recognize which products cannot be produced as planned because of failure in the material and postponed manufacturing because of that.

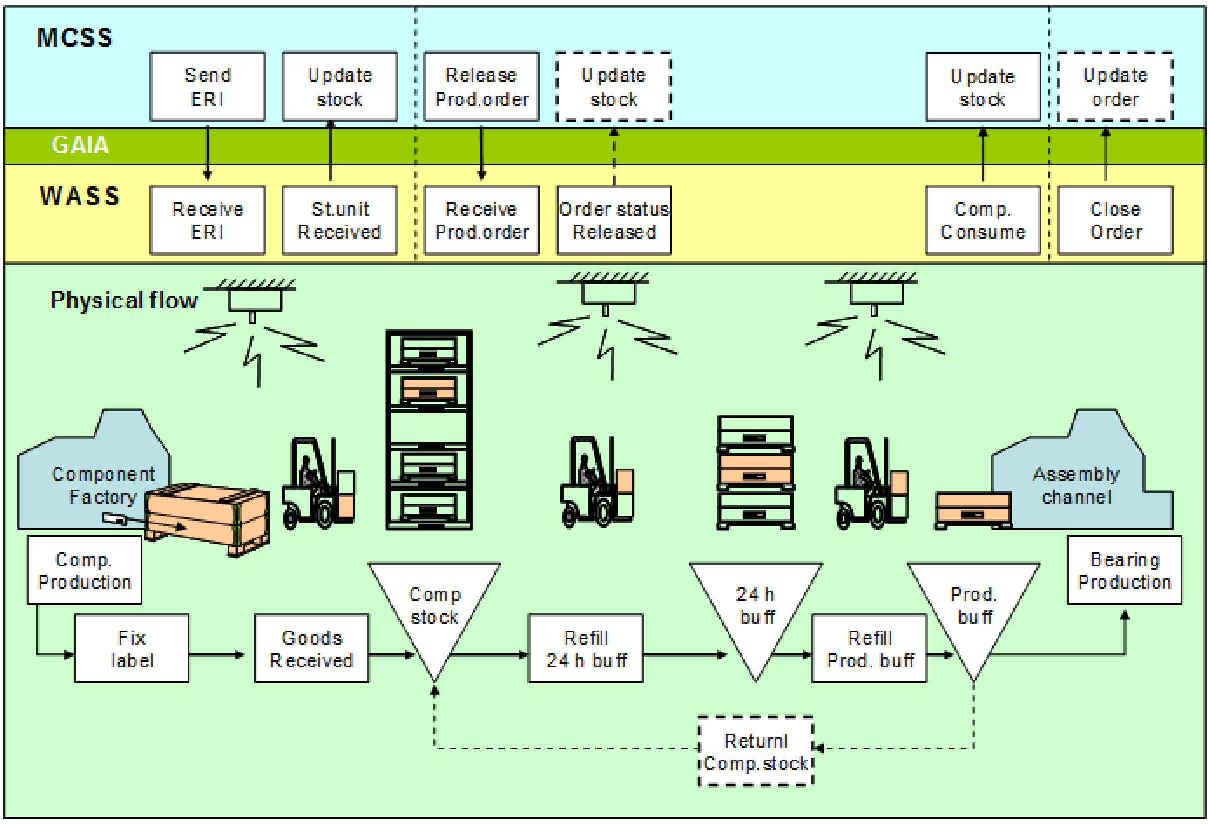


Figure 6.30: Information flow for use of WASS, Source: SKF

6.5.2 Communication System

More important for the operations inside the E-factory is the way how information is communicated between the employees and influence their work. There are different actors that send or receive information. As main actors the supply chain department, the warehouse, the channel managers/operators and the forklift drivers can be identified (see Figure 6.31). It is important to make sure that all information that needs to be communicated has an underlying communication system that enables effective communication.

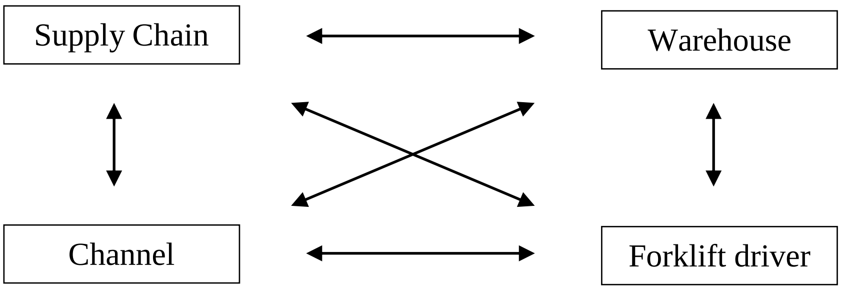


Figure 6.31: Information flows

But first of all it is important to identify which information needs to be communicated and which characteristics the information has (see chapter 3.5.1). Table 6.38 shows an overview of who is communication what to whom. The table contains the two way communication and displays which information the actor written in the first column provides or share for the respective actor written in the first row.

Table 6.38: Information exchange between involved actors

→	Supply Chain	Warehouse	Channel	Forklift driver
Supply Chain	x	Upcoming production and required material, regular and structured through MCSS access	Upcoming production, sequence list, production plan changes, shared within MCSS	Sequence list to sort and move the right material at the right time, WASS will be used for communication
Warehouse	Incoming material, missing material, storage levels, uses MCSS for regular communication and other systems for spontaneous information exchange	x	Storage levels e.g. for returned goods, incoming material, on request through MCSS, spontaneous information through mail or phone	Which material to move when and where, production plan, communication to mobile units with WASS, reachable for spontaneous tasks, meeting
Channel	Problems, production/finished products amounts, capacity, continuous communication, meetings	Returned material, today they order components every day, order consumable material, order via MCSS every morning	x	Urgent material movements, visual buffer control, spontaneous communication should always be possible
Forklift driver	No regular communication, should have opportunity to communicate problems and improvements	Problems, irregularities, meeting every morning	Problems, spontaneous communication	x

It can be seen that the normal top down information flow from supply chain to warehouse and channel as well as further to the forklift drivers is enlarged with a feedback flow. This is important because material is frequently discarded in production which hinders the exact planning of production amounts and requires information flows of divergence from planned production. In addition, SKF is very successful with their implementation of six sigma principles and this has led to daily meetings where deviations from planned processes are reported. The factory manager, supply chain department and channel managers participate on these meetings and problems are reported and a solution can be found together.

Because information sharing and communication are so important for a successful production, well established mediums should be used for this purpose. For the structured and continuously shared information MCSS is mainly used (see Figure 6.32) and with the implementation of WASS future information flows will be structured and standardized. WASS will make the information flow much easier but it is important to ensure flexibility and feedback opportunities. The dynamic environment and spontaneous changes in the production sequences muss be able to be included in WASS operations. This is especially important in the E-factory because of many customized bearings and long throughput times. At the current stage WASS operations are exclusively based on sequence lists and the task creation based on finishing products. It is not possible yet to create tasks outside the sequence list or to prioritize task which the forklift drivers should perform. Furthermore, the handling of load carriers and returned material is not yet included in the WASS software and will require other communication ways to perform the complete production process (P4).

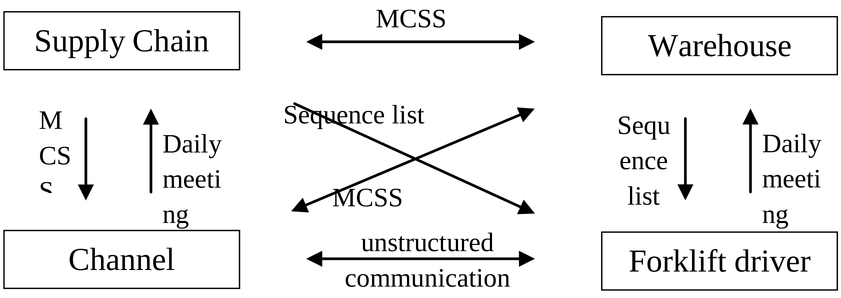


Figure 6.32: Information flow mediums

The importance of communication became clear in the previous part but it is also important to consider the amount and efficiency of the purposed communication media. Regarding this consideration the trade-off between standardization and flexible, continuous communication should be analyzed. Taking the example of the arrival of a truck or trailer that delivers the components to the E-factory. The truck can always arrive at 9am and 15 pm or the forklift driver could get some kind of signal each time a truck arrives. The same question should be asked for buffers of load carriers that have maximum levels that define when they should be picked up latest. The forklift drivers could look around every day which buffer need to be emptied today or they could get a signal just when a buffer is full. And another question is who should send these signals. To find answers to these questions it is important to analyze weather the task can be efficiently standardized, how frequent they occur and how signals can be send. The truck arrival is very regular at the current process of operations but sending a signal could also be implemented for example when leaving the warehouse or through pressing a button after arrival. For the load carrier buffers and returned material the frequency is very irregular (P4) and this task would be much more efficient with the implementation of a communication system to handle these tasks. But the signal creation is also more complicated because various buffers exist and would need to be clearly defined and separated in order to enable task creation.

6.5.3 Identification Systems

At the E-factory all materials and finished bearings are marked with a product label, which is most of the times attached to the load carrier e.g. pallet frame. There are many different product labels based from which supplier the material come, but also SKF uses many different versions (P21). Figure 6.33 shows a scheme of a label on material that comes from a supplier outside SKF. It shows information about sender and receiver, which product type the load carrier contains, the amount of parts and further component specific information. In addition, it shows a barcode to be able to collect information automatically through scanning the barcode. At the current stage, the E-factory does not use barcode scanners but this will be the case with the implementation of WASS. When using barcode scanning it is important to make clear which barcode to scan when there are several ones provided in the same label.

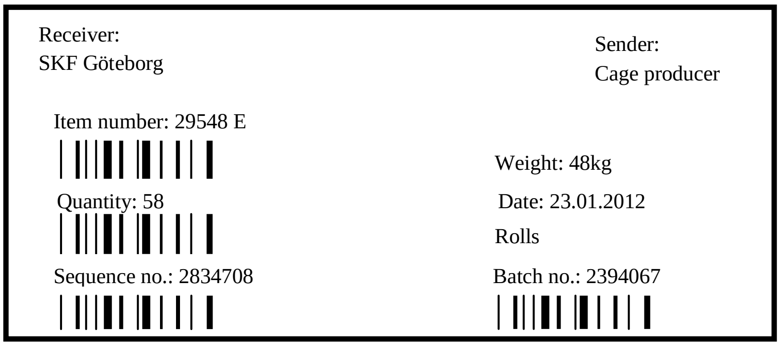


Figure 6.33: Product label extern supplier

Components that are moved within SKF like the hardened rings or the finished rollers have different labels that contain less information and do usually not have a barcode (see Figure 6.34). Until the implementation of WASS even these labels need to have barcodes and the E-heat treatment needs to start printing barcodes on their labels. Labels do also vary in color in order to make a distinction between them easier. For example the A-heat treatment uses green paper and the E-heat treatment white paper. For the forklift drivers as well as the channel operators is it crucial to get the information from this label to match the right components and to deliver the whole batch size.

Figure 6.34: Product label used only inside SKF

The finished products are labeled each package separately with information for the customer i.e. name of the product and type number as well as the brand name SKF. The load carriers that contain several finished bearings as well as bearing boxes that do not require any other load carrier are market with a label that is used for identification at the central storage for finished products (see Figure 6.35). Because the central storage already uses WASS, the label must include a barcode. These labels have the advantage that they just have one barcode which remove difficulties during scanning.

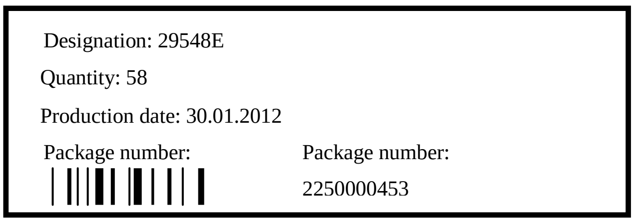


Figure 6.35: Product label load carrier finished products

The many different kinds of labels used and information on them make it necessary to create a substantial amount of different labels and to mark them again after each production step. Furthermore, WASS will require that every load carrier is scanned after all rings or components are used. This is an extra working step for the employees and the implementation may meet resistance. Another aspect is that barcode scanning is an easy but quite old technique that can be replaced by superior methods like RFID or cameras that identify locations and filling levels of buffers. Implementing a newer system from the beginning may reduce future investments when handling needs to be further improved.

Table 6.39: Possible improvements information flow analysis

Problem	*Possible Improvement*
P19: Not using the same sequence list	S17: Use the same sequence list
P4: Irregular production and material needs	S4: Communication device for channels and SLS
P21: Different product labels	S18: Use the same product labels

Table 6.40: Solution Overview

Solution Overview	
S 1: Rings, finished bearings and packaging material on half-pallets S 2: Intermediate buffer zones closer to the channels S 3: SLS more tasks, operates 24/7 and later WASS S 4: Communication device for channels and SLS S 5: Remove equipment without replacement S 6: Replace equipment with a scissor table or similar equipment S 7: Replace equipment with other/ more adapted equipment S 8: Roller conveyer before first machine S 9: Organise and structure buffer zones, assign routines	S 10: Divide aisles into people and traffic S 11: Reconstruct aisle between LT5 and LR1 S 12: SLS uses stacker to reach finished products from LT5 and LR1 S 13: Separate inside and outside forklift drivers S 14: Loading dock with storage area S 15: New porch roof with wind protected shelter S 16: Organise new intermediate component storage S 17: Use the same sequence list S 18: Use the same product labels

7 Solution

In this chapter the previous identified possible improvements will be evaluated in order to propose an action plan for the order of implementation. After describing the solution assessment, the evaluation framework will be described and used to group and prioritize the solutions for the action plan.

7.1 Solution Assessment

The possible improvements which are included in the previous analysis part result from many various sources and feedback was received related to a possible implementation. Some of the possible solutions for the different problems originate from the already decided future changes that where explained during the conducted interviews. Other improvement options resulted from the interviews with the channel managers who were asked in an open question to say which ways of improvement they can imagine. The literature around this topic was very helpful in describing how certain issues should be handled in the best way and this made it possible to compare the current situation at SKF with related theory. In addition, the extensive observations inside the E-factory as well as the visit to the better organized D-factory resulted in a clear problem understanding followed by a sense of which solutions are helpful and at the same time possible within SKF.

All the possible solutions (see Table 7.1) were discussed with channel operators, channel managers or other employees based on their responsibilities and tasks within SKF. The regular meetings with the thesis supervisor gave a perfect opportunity to receive feedback for related considerations. The reaction and feedback regarding the proposals drew the attention towards various constraints and difficulties related to their implementation but showed even further opportunities that are imaginable. Reactions on proposals also gave a good sense on what acceptance for the respective solution can be expected. Through the observations of the operations it was possible to assess the effect the problem solutions would have on the efficiency of the whole production.

Table 7.1: Solutions with description

Solution	Description
S1: Rings, finished bearings and packaging material on half-pallets	Heat treatment need to be programed to place rings on half-pallets, space for less than half the amount (cannot use middle), supplier of cartons must place them on half-pallets
S2: Intermediate buffer zone closer to the channels	To reduce movement distances, space constraints, only interim solution
S3: SLS more tasks, operates 24/7 and later WASS	Decided change, ease the implementation by a stepwise transfer of work to SLS, very important for WASS implementation
S4: Communication device for channels and SLS	To be able to cope with complexity and to provide flexibility and reduce uncertainty, should be in place before WASS to ease acceptance
S5: Remove equipment without replacement	Equipment that at latest with the implementation of WASS is superfluous can be removed, problem with acceptance of operators
S6: Replace equipment with a scissor table or similar equipment	Reduce maintenance costs and is adapted to security standards
S7: Replace with other/ more adapted equipment	The analysis identified not adapted equipment which should be replaced, replacement of leasing contract is a problem
S8: Roller conveyer before first machine	In connection with WASS would one material movement be avoided
S9: Organize and structure buffer zones, assign routines	Necessity for the implementation of WASS enable the transfer of tasks to SLS
S10: Divide aisles into people and traffic	Need to be done for safety reasons, difficult because of space limitations
S11: Reconstruct aisle between LT5 and LR1	Aisle need to enable forklift truck traffic to make it possible to use WASS for LT5 and LR1, space limitations
S12: SLS uses stacker to reach finished products in LT5 and LR1	To enable that SLS already know can serve the end of LT5 and LR1 they can use stackers, problems with acceptance of operators, interim solution
S13:Separate inside and outside forklift drivers	Clean factory requirement for high quality production, need the construction of appropriate gates and docks
S14: Loading dock with storage area	Proposal from the future layout team, reduce material handling, increase space inside factory, enable separate inside traffic, high cost
S15: New porch roof with wind protected shelter	Space constraints adapted solution for cleaner factory and limited buffer spaces
S16: Organize new intermediate component storage	Incorporate the space requirements from supply chain, need to be structured to reach high efficiency
S17: Use the same sequence list	E-heat treatment need to follow the same list, system for placing on roller conveyors need to be implemented
S18: Use the same product labels	To reduce confusion during scanning, agreement with suppliers about label design

7.2 Evaluation Framework

In order to evaluate the solutions which were identified in the analysis a framework that includes three parameters was developed. The evaluation (see Table 7.2) will show where the advantages and disadvantages of each solution are and what needs to be considered carefully during an implementation. The three parameters are:

- Effect: which level of improvement in monetary terms can be reached through the implementation of the respective solution (+++: very high effect, ---: very low effect)

- Cost: which expenses for SKF are related to the solution (+++: very low costs, ---: very high costs)
- Implementation: how difficult will the implementation be including required training and changes of routines as well as how the employees will react to the changes and which risks for production are connected with the implementation (green: very easy to implement, red: very hard to implement)

Table 7.2: Solution Evaluation

Solution	Effect	Costs	Imple-mentation
S1: Rings, finished bearings and packaging material on half-pallets	+	++	
S2: Intermediate buffer zone closer to the channels	-	+	
S3: SLS more tasks, operates 24/7 and later WASS	+++	---	
S4: Communication device for channels and SLS	-	+	
S5: Remove equipment without replacement	+++	+++	
S6: Replace equipment with a scissor table or similar equipment	+	-	
S7: Replace equipment with other/ more adapted equipment	-	--	
S8: Roller conveyer before first machine	+	-	
S9: Organize and structure buffer zones inside the channels, assign routines	++	++	
S10: Divide aisles into people and traffic	--	-	
S11: Reconstruct aisle between LT5 and LR1	+++	--	
S12: SLS uses stacker to reach finished products from LT5 and LR1	-	+	
S13:Separate inside and outside forklift drivers	+	-	
S14: Loading dock with storage area	++	---	
S15: New porch roof with wind protected shelter	---	--	
S16: Organize new intermediate component storage	-	++	
S17: Use the same sequence list	+	+	
S18: Use the same product labels	-	+	

7.3 Prioritization

For the decision making regarding which solution to choose the most important parameters are effect and cost. Based on them it is chosen which of them should be considered first. The evaluation of the difficulty of implementation has a lower impact on the decision of when to implement them but has impact on how much planning and implementation work is required. This is important to know in order to assign resources and time to the implementation processes. Using the evaluation in Table 7.2 the solutions are plot based on effect and cost as well as the color of the circles view the difficulty of their implementation (see Figure 7.1).

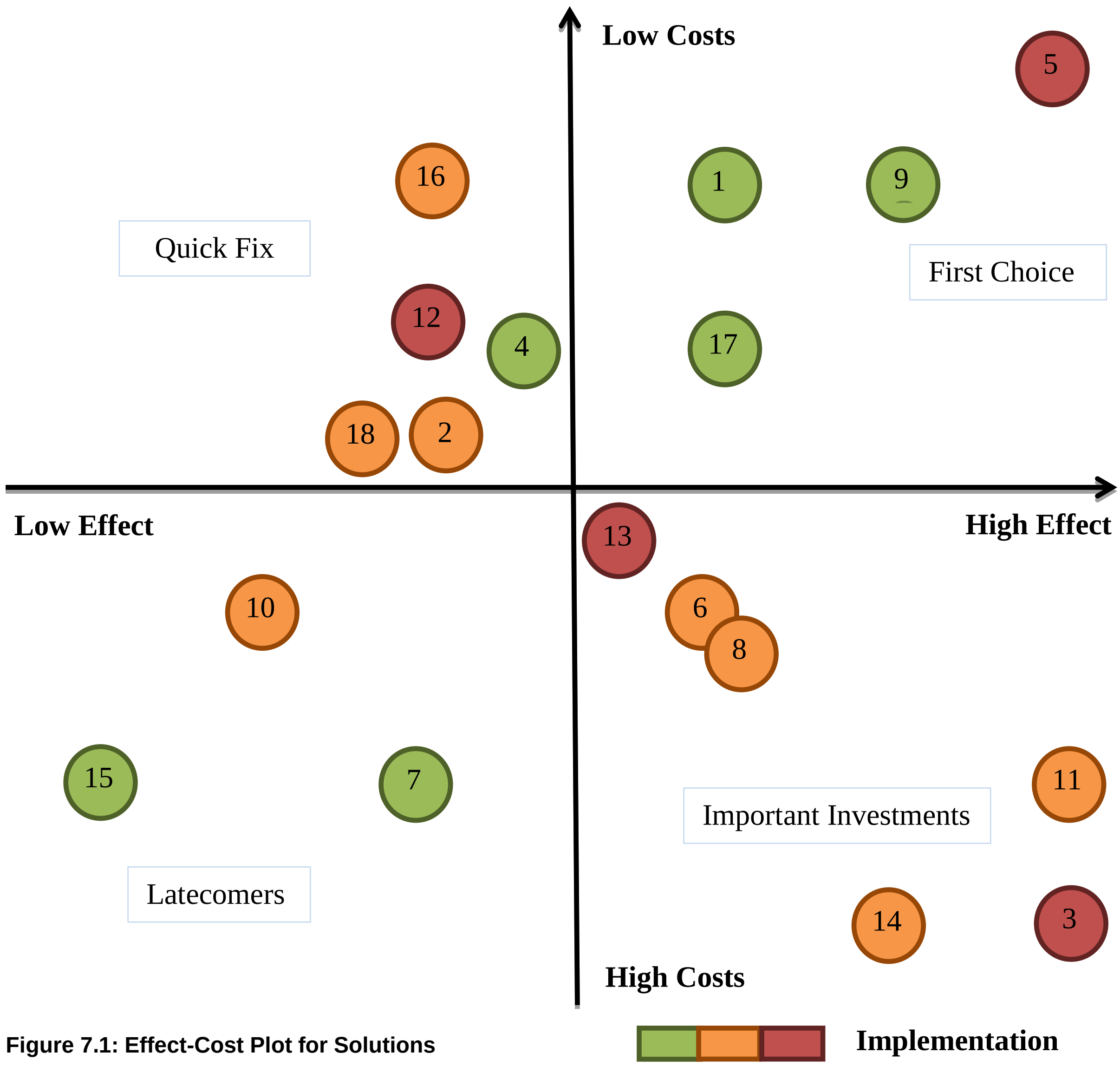


Figure 7.1: Effect-Cost Plot for Solutions

After plotting the solutions they can be divided into four groups based on their position in the graph. These groups can be labeled:

- First Choice: solutions with high effect for low costs, which should be implemented as soon as possible with having in mind the implementation parameter.
- Important Investments: a high effect can be reached after significant investments, these solutions need more planning and considerations before their implementation to do the things right
- Latecomers: these solutions lead to a relative small effect reached through quite high investments, therefore should they be postponed until the main other solutions are implemented
- Quick Fix: solutions that do not have a specially high effect but this effect can be reached with quite low cost and therefore should they be considered for implementation from the beginning

The different groups can be used very well for the prioritization of the solutions, because the first choice solutions should be considered first and the latecomers latest. The important investments should be planned as soon as possible and the quick fix solutions should be implemented when it is most convenient.

7.4 Action Plan

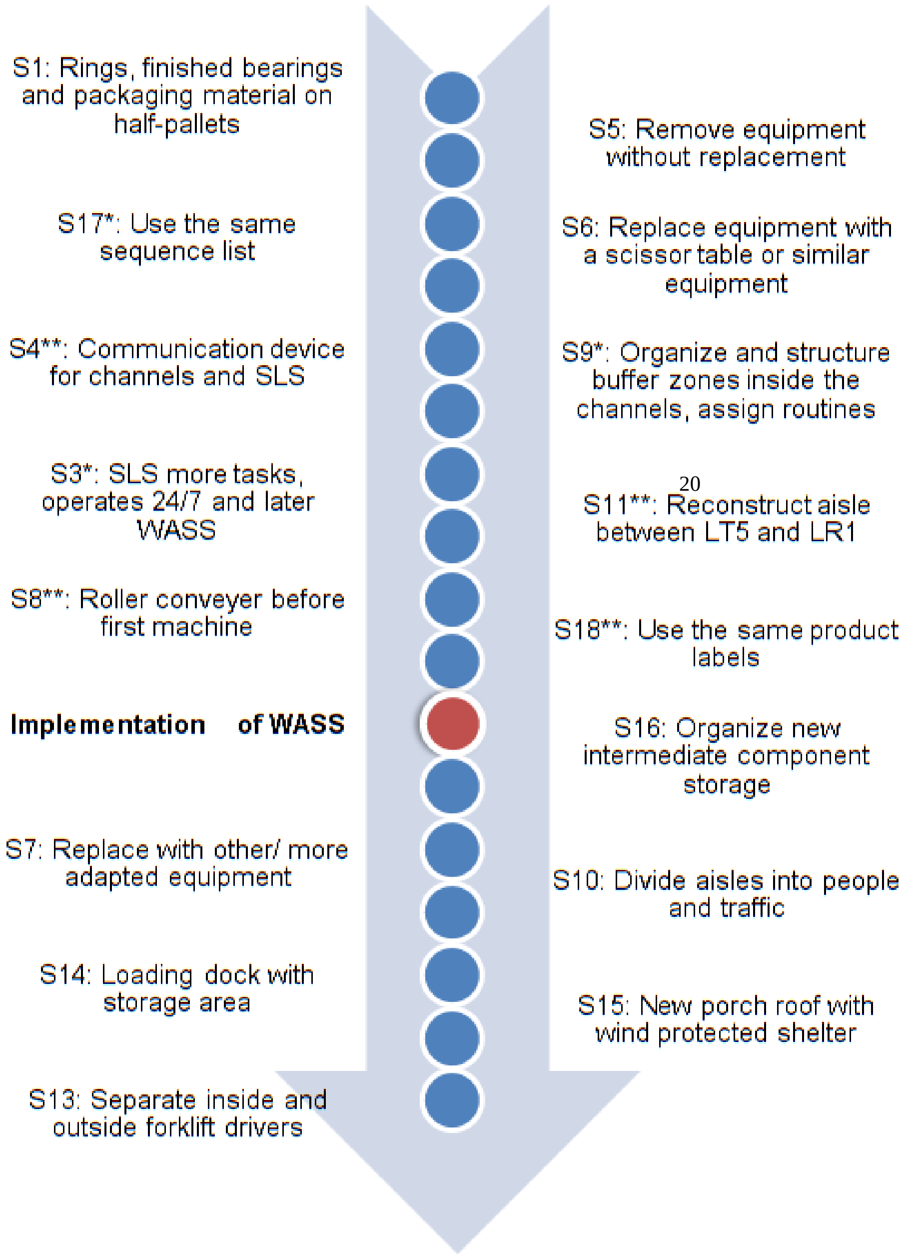
For the decision making within one group such as: first choice, the implementation parameter is very helpful because it gives an idea of which ones are easier to implement, better accepted, possible quite early and do not imply much risk. Using all this information together with considerations about first possible point in time for their implementation and their relation to the start of using WASS, the purposed implementation order can be displayed in a timeline (see Figure 7.2).

7.4.1 Considerations before Creating the Action Plan

The recommended order for the implementation of the solutions will be based on the Effect-Cost plot in the previous section. Because the attention should be on solutions that solve problems in the long term and which are implemented as soon as possible, the interim solutions S2 and S12 are not included in the recommended action plan because they do not solve the problems in the best way. The most significant event included in the action plan is the implementation of WASS planned in 2013. Some of the solutions are required to be implemented before WASS will be in use and therefore need to be taken into careful consideration. The action plan views the recommended order for the implementation, but as seen in the evaluation framework (see Table 7.2) the solutions require different planning periods which have to start earlier. The fact that all improvements in the best case should be implemented as soon as possible but that the focus should be on that ones with the highest effect, let to this action plan in Figure 7.2 without specific points of time.

7.4.2 Position Explanation for the Action Plan

Considering that S17, S9 and S3 have to be implemented before WASS can work, places them quite early in the action plan. In addition, S17 and S9 are part of the “first choice” group places them even higher up, but S9 will have the highest effect first with the implementation of WASS and need to be adapted to it from the beginning. The solutions that should be in place before the WASS implementation are all included either in the “quick fix” or “important investment” group and are positioned in the action plan based on their effect already before the WASS implementation and their impact on the other solutions. S3 should be implemented stepwise so that SLS takes over more tasks (see Appendix 3) to get used to the tasks they will get with WASS and make the implementation easier. For example can a communication device (S4) be a great help already before WASS but the adaption of product labels will only have a positive effect in connection to the use of WASS.



*must be in place before WASS

**should be in place before WASS

Figure 7.2: Action Plan

S1, a "first choice" solution, is positioned in the first place because it will not change any routines and is not depended on any of the other solutions. The solutions related to the reduction of expenses for material handling equipment (S5 and S6) should be considered quite early because the cost reduction was one of the major purposes of this work, even if the solutions require more resources and planning for their implementation. The solutions that are positioned after the WASS implementation are either part of the "latecomers" group or based on the construction process which may not be finished before 2013. Furthermore, S13 is depended on the implementation of S14 and S15 to be able to divide indoor and outdoor traffic.

8 Discussions and Conclusion

This part discusses the results with regard to their quality and how useful they are for SKF. Furthermore, the methodology will be critically revised in order to evaluate the usage and to identify possible improvements.

8.1 Result Discussion

As stated in the research question, the purpose of this work was to better align production and logistics in SKF's E-factory. There were many problems that were obvious from the beginning and which were named again and again during the major observation phase. But through the mapping of the current situation to get a holistic view and to find relationships between the different areas and functions within the factory additional problems became visible and could be related to the other known problems. The root cause analysis made it possible to find the real reasons behind the many sub problems that could be identified and that enabled a focused analysis of the root causes to find efficient long-term solutions. The following four sections will try to summarize the findings related to the sub questions of the underlying research question stated in section 1.3.

8.1.1 Shift of Responsibilities

The first sub question considered the division of work to utilize competencies efficiently. The channel operators do a lot of transportation work which is supposed to be handled more efficiently by the SLS operators which have their competence in performing various material movements. Why this is not the case in the E-factory has different reasons based on the characteristics of the considered movement. Each of the tasks that preferably should be performed by SLS has been considered separately and it was identified what is required to shift the responsibilities. After the implementation of this recommendations the operators can focus on their competences and productivity is increased which will positively affect financial results.

8.1.2 Replacement of Handling Equipment

How to use handling equipment most efficiently was the content of the second sub question. A detailed analysis of all handling equipment that is owned by the E-factory and leased from an outside SKF provider was conducted and resulted in a clear overview of the equipment. The usage and characteristics as well as requirements for the performed tasks were carefully analyzed. Furthermore, it was considered that the frequently used Kentrucks need to be replaced and alternatives are required. With all this considerations each single truck or stacker was analyzed with regard to alternative and more adapted equipment. In addition, several devices used for material handling were found to be superfluous or not in use. Taking all the proposed changes together the E-factory could save between 150 000 SEK and 300 000 SEK in annual leasing payments. Cost for the purchase of alternative equipment like scissor table that are not leased will reduce this saving only in the short term. Furthermore, the leasing contracts have a maturity of 5 years and even if equipment can be exchanged within SKF it may be difficult to immediately get rid of some equipment.

8.1.3 Adapting Factory Layout

The third sub question was concerned about the support the factory layout can give on a better alignment of production and logistics. The problem is that during the last five years more and more channels were installed in the E-factory and plans changing continuously resulted in a production layout that is not very well adapted to the required logistics. Inaccessible areas, narrow aisles and long movements are the consequences of insufficient considerations of logistics requirements. To adapt logistics and production to each other afterwards is quite difficult. Moving machines to new places or reconstruct gates and loading docks is hard to realize, need a lot of planning or is quite expensive. But to keep a high quality and to reduce defects it is important to establish a clean and dry factory because the alternative costs for products with bad quality may be very high but hard to estimate. However, to enable a separation of inside and outside forklifts requires extensive changes in routines and layout and will not be possible to implement in the short term.

Other changes that are already planned may also have requirements on the factory layout. The implementation of WASS has clear rules how every buffer area has to look like and this need to be incorporated in the current layout. These changes have to be made to make the system work and all buffers should be accessible by forklifts. In addition, factory layout plays a very important role in the case of amount of material movements. Decreasing the movements will at the same time reduce required time and handling equipment.

8.1.4 Standardize Information Flows

The last sub question that should be answered in this work was how the information system should be organized to give best support. The use of modern information system within the organization of material supply has not come that far in SKF’s E-factory yet. Most of the movement work is governed by the visual cognition of type numbers, amounts and sequences. Many plans are on the minds of the employees but implementation is difficult and a process that takes a very long time. Problems here can be seen in the lack of standardization and that everyone waits for the system that solves everything at the same time. This will hopefully happen with the implementation of WASS but until then it will be hard to motivate the employees for earlier changes which will then be replaced by WASS again. In addition, changes in information flows influence many departments and levels within the company and cross-function changes and implementations are in general more difficult. But also WASS will not solve everything and it is every important to be aware of the limitation of WASS and how it needs to be adapted to work sufficient in the E-factory.

8.2 Conclusion

To be asked to improve the situation in a complex factory logistics environment is not an easy task. It requires that all material and information flows are understood perfectly. Routines and working behavior need to be considered as well as opportunities and constraints have to be included. To isolate problems and solve each of them separately does not work because of the big influence on each other.

The uniqueness of every production facility and their processes make it impossible to use a predefined method for solving the problems that are specific for SKF’s E-factory. As stated in section 1.3, the purpose of this work was to develop a method to be able to handle the situation systematically and to base it on the research question to keep focus on the crucial problems. The developed Production Logistics Remedy (Figure 4.2) went from symptoms over root causes to the solution with the help of an in depth analysis and a solution creation process. This whole process was supported by comprehensive data collection. The interviews conducted where a very valuable source for the data and the fact that people from various departments where interviewed made the information very reliable. But still, the gathering of more quantitative data could have been valuable during the solution creation and to verify the solutions.

The analysis part was adapted to the specific factors occurring in the E-factory like the focus on already decided future changes. In order to apply the method within other complex factory environments it needs to be more generalized. Furthermore, to use the root-cause analysis after the problem identification can be in some way confusion and could be replaced by a kind of problem grouping and to base the further analysis on this grouping of problems.

The solution creation process is based on the consideration that it will not be possible to find a single solution that solves all problems. The objective with the solution creation was to evaluate and prioritize the solutions to create an action plan for the implementation process. The distinction between problems that have to be implemented or should be implemented is also helpful in the decision making process. In summary it can be said that the Production Logistics Remedy is suitable to be used for similar settings because it can be adapt to individual settings and guides the way to the solution.

To use the findings of this work in an appropriate way for SKF and to manage the implementation process it is important to divide responsibilities for the different solutions. When someone is in charge of the implementation of one of the solutions it will be much more likely that an efficient implementation process starts. The fact that the factory environment changes so rapidly will also lead to a situation where solutions must be adapted to the current situations. This requires a high awareness and the adaption to changing situations was one of the most difficult tasks with this work. Hopefully, the used method will be further developed in order to ease and structure the handling of this kind of problems. Besides continuing research to generalize a method for complex production logistics, the field itself should be covered more holistic in literature. For example research does not cover how functional division of logistics and production should work inside a company because the focus is mainly on 3PL providers outside the company. In addition, the use of IT systems and their implementation would need further examination to be a better support for companies in this situation. Another point is that the main literature about factory layout is quite old and should be upgraded with recent findings. In general the topic stands between two big topics that are often covered separately in literature and holistic views are unfortunately seldom provided.

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Appendices

Appendix 1: Questionnaire to Channel Managers

Channel: __________________________Number of products: _________________________

Capacity utilization: _________________ Setup time: __________________________________

When does the same product type come back into production: _________________________

How long time in advance is there a sequence list? ____________________________________

How frequently is the sequence list change? ____

MTS ☐ MTO ☐

Demand point	How often is the procedure done?	How long time does the movement take?	Time Window	What kind of equipment is used for the task?
	Component flow (Roller, Cages)			
HF-200 -> Intermediate storage area				
Intermediate storage area > Channel				
	Rings (Hardened)			
EHT-> Roller conveyers				
Roller conveyers ->Channel				
	Packaging (for finished products)			
HF-200-> Intermediate storage area				
Intermediate storage area ->End of channel				
	Finished products			
End of channel -> Intermediate storage area				
Intermediate storage area ->Central storage				

	Returned products			
Channel (Assembly) ->HF-200				
HF-200-> Intermediate storage area				
Intermediate storage area -> Channel (Assembly)				

Flow: return load carriers

Demand point	Transfer to:	How often is the procedure done?	How long time does it take?	Time Window	What kind of equipment is used for the task?

Appendix 2: Handling Equipment with Replacement Alternative

Internal code	Model	Place of usage	Main area of function	Lifting features	Equipment fork length currently	Fork lenght required for movement	Possible improvements
LT5							
881	Kentruck ERGO 800B	Assembly, Inspection/ transporting rings	Lifting/transporting	Medium	Long	Short	Replace with scissor table or similar equipment
514	Kentruck ERGO 800B	Assembly, Inspection/ transporting rings	Lifting/transporting	Medium	Long	Short	Replace with scissor table or similar equipment
879	Kentruck ERGO 800B	Assembly, Inspection/ transporting rings	Lifting/transporting	Medium	Long	Short	Replace with scissor table or similar equipment
745	Kentruck ERGO 800B	Assembly, Inspection/ transporting rings	Lifting/transporting	Medium	Long	Short	Replace with scissor table or similar equipment
515	Kentruck ERGO 800B	Assembly, Inspection/ transporting rings	Lifting/transporting	Medium	Long	Short	Replace with scissor table or similar equipment
1295	Hyster 1.0S	Transporting rings to robot	Lifting/transporting	High	Long	Long	Replace with more adapted equipment
1043	Hyster 1.2S	Transporting finished products	Lifting/transporting	High	Long	Long	SLS more tasks, operates 24-7 and later WASS
LT4							
1077	Kentruck ERGO 800B	Assembly	Lifting/transporting cages	Medium	Short	Short	Replace with scissor table or similar equipment
1078	Kentruck ERGO 800B	Assembly	Lifting/transporting rollers	Medium	Short	Short	Replace with scissor table or similar equipment
1079	Kentruck ERGO 800B	End of processing	Lifting inner rings	Medium	Short	Short	Replace with scissor table or similar equipment
1080	Kentruck ERGO 800B	Assembly	Lifting/transporting outer rings	Medium	Short	Short	Replace with scissor table or similar equipment
1081	Kentruck ERGO 800B	Beginning of processing	Lifting inner rings	Medium	Short	Short	Replace with scissor table or similar equipment
1082	Kentruck ERGO 800B	Assembly	Lifting/transporting inner rings	High	Short	Long	Replace with scissor table or similar equipment
1083	Kentruck ERGO 800B	Bufferzone	Transporting outer & inner rings to processing	High	Long	Short	Replace with scissor table or similar equipment
1076	Hyster 1.0S	End of channel	Transporting finshed products to external bufferzone	High	Long	Long	SLS more tasks, operates 24-7 and later WASS
LT3							
963	Hyster E2,00XMS	End of channel	Lifting/transporting components & finished goods	High	Long	Long	SLS more tasks, operates 24-7 and later WASS
1177	Hyster RP2.0	Assembly	Collecting rings from external bufferpoint	High	Long	Long	Remove without replacement
1028	Hyster S1.0E	Assembly	Lifting/transporting rollers	High	Short	Short	Replace with scissor table or similar equipment
1029	Hyster S1.0E	Assembly	Lifting/transporting rollers	High	Short	Short	Replace with scissor table or similar equipment
1052	Hyster S1,5S-IL	Beginning of channel	Lifting/transporting rings	High	Long	Long	Roller conveyer before first machine
LT2							
989	Kentruck ERGO 800B	Begining of channel	Lifting/transporting inner rings to inspection	Medium	Short	Short	Replace with scissor table or similar equipment
1164	Hyster S1,5S	Face grinding	Lifting/Transporting rings from face grinding	High	Long	Long	SLS more tasks, operates 24-7 and later WASS
K30							
1227	Hyster P2,0S	End of channel	Lifting/transporting material	Low	Long	Long	Remove without replacement
974	Hyster S1,0	Assembly	Lifting rollers	High	Short	Short	none
1268	Atlet ERGO AJN 160 S TFV 360	Assembly/End of channel	Lifting/transporting rings wodden crates and finished products	High	Extra long	Extra long	SLS more tasks, operates 24-7 and later WASS
1265	Hyster RP 3,0 (Sped 4,5)	Assembly/End of channel	Lifting/transporting rings wodden crates and finished products	Low	Extra long	Extra long	none
1266	Hyster 3,5	Beginning of channel/End of channel	Lifting/transporting rings	High	Extra long	Extra long	SLS more tasks, operates 24-7 and later WASS
LR1							
510	Kentruck ERGO 800B	Robot cell	Lifting/transporting rollers	Medium	Long	Short	Replace with a scissor table or more adapted equipment
671	Kentruck B69E	Assembly	Special equipment transporting green metal boxes	Medium	Special forks	Special forks	Replace with more adapted equipment
546	Kentruck ERGO 800B	Assembly	Lifting/transporting rollers	Medium	Long	Short	Replace with a scissor table or more adapted equipment
157221	Kentruck ERGO 800B	Assembly	Lifting/transporting rollers	Medium	Long	Short	Replace with a scissor table or more adapted equipment
780	Hyster E1,75XM	Beginning of channel	Transporting rollers to and from RK-factory	Medium	Long	Short	SLS more tasks, operates 24-7 and later WASS
1294	Hyster S1,5S	Beginning of channel	Collecting material from bufferzone/transporting rollers inside LR1	Medium	Long	Short	none
1038	Hyster S1,0E	End of channel	Lifting/transporting rollers inside LR1	High	Long	Long	SLS more tasks, operates 24-7 and later WASS
CARB							
803	Kentruck ERGO 800B	Inside of channel	Multiple purposes	Medium	Short	Short	Replace with more adapted equipment
1281	Hyster S1,5S	End/Beginning of channel	Lifting/Transporting rings and finished products	High	Long	Long	SLS more tasks, operates 24-7 and later WASS
Heat treatment							
1182	Hyster E1,75XM	End of channel	Lifting/transporting rings to roller conveyers	High	Long	Long	none
1184	Hyster S1,5S	End of channel	Lifting rings in the manual packing station in the end of Heaton 2	High	Long	Long	none
1181	Hyster E1,75XM	Beginning of channel	Lifting/transporting rings to the beginning of Heaton 2	High	Long	Long	none

Appendix 3: Tasks SLS can take over before WASS Implementation

LT4

- Deliver components (cages rollers) to channel from intermediate storage area
- Collect finished products
- Collect EUR-pallets and pallet covers *

LT3

- Collect and deliver white rings to assembly
- Collect load carriers in assembly*
- Collect finished products
- Collect empty EUR-pallets in the beginning of the channel*

LT2

- Collect empty EUR-pallets in the beginning of the channel*

LR1

- SLS collects and delivers all rollers to and from RK-factory
- Collects finished products in the beginning of the channel

CARB

- Place rings on roller conveyer.
- Collect finished products.

*Can be taken over by SLS immediately