Master Thesis

Supply and disposal of production lines with trailer systems

by

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Abstract

At modern automotive production plants the use of trailer route system for transport goods and materials between the production lines and the storage facilities can be seen as a general trend.
At MAHLE Filtersysteme Austria in St. Michael ob Bleiburg such trailer systems in combination with forklifts are in use for supply and disposal of production lines. The optimization of these trailer route systems is the main target of this thesis.
Trailer systems are having a higher capacity on long distances than forklifts as well as the working conditions for the drivers are better than for forklift drivers. Using trailer systems creates overall saver work conditions, delivers more material per ride and it evens the material flow. To best utilize these advantages it is needed to run such trailer systems on pre-defined cycle. Unpredictable production line downtimes, -new set ups or unplanned shut downs make these pre-defined cycles hard to fulfil.
This thesis is focusing on the supply- and disposal of production lines done with trailer route systems at segment 15 of MAHLE Filtersysteme producing oil filter modules. This segment is used as the flagship for the analysis, measurements, improvements and optimizations.
During the project time of this thesis one production line has fully been converted to trailer route system supply. By this change one workplace was saved at the production line but introduced a new job at the warehouse as an order picker. The new order picker could be utilized several other improvements were needed to be done.
A spread sheet showing the number of needed SLCs per production line and the related inventory ranges has been developed. Furthermore the required transport capacity of the transport trolleys can be found in this spread sheet.
Develop standardized trailer route system processes, test them and bring them into operation was another main target of this thesis.

Acknowledgment

First I want to thank the whole Supply Chain Management team of MAHLE Filtersysteme for their help and supervision during my thesis. Especially I want to thank Mr. Rogerio do Carmo and Mr. Dirk Paganal for their great support.

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Finally thanks to all my friends and fellow students for the great time we had together.

Table of content

1 Description of the MAHLE group and its plant in Carinthia St. Michael ob Bleiburg

1.1 Company MAHLE group

1920 Hermann Mahle and Hellmuth Hirth founded Versuchsbau Hellmuth Hirth

1921 the first serial produced leigh metal pistons were produced in Europe.

1922 Hermann's brother Ernst Mahle also joined the company. In that, time pistons for car engines were mostly produced with heavy grey cast iron so the two tried to build pistons with light metal.

1938 the company MAHLE was transformed out of the previous company called Stuttgart-Cannstatt (EC). From that time on the company grew yearly and produced more and more pistons and filter systems.

1964 Herman and Dr. Ernst Mahle founded the MAHLE-Foundation GmbH.

In the 1970's the globalization of the MAHLE GmbH started.

1972 MAHLE bought company shares of the Knecht Filterwerke GmbH located in St. Michael ob Bleiburg, Carinthia, Austria.

1992 MAHLE bought all company shares of the Knecht Filterwerke GmbH.

Since 1999 the Company Knecht Filterwerke GmbH is renamed in MAHLE Filtersysteme GmbH.

2003 the first MAHLE engine, a three-cylinder racing engine for Formula SAE was developed and produced. (MAHLE)

The MAHLE group has four-business units: (MAHLE)

- Engine Systems and Components
- Filtration and Engine Peripherals
- Thermal Management
- Aftermarket

The company is located on five continents and has approximately 75000 employees worldwide. In every second worldwide sold car is a component of the MAHLE group installed.

1.2 The plant in Carinthia

Figure 1-1: Plant of MAHLE Filtersysteme Austria GmbH

The pant in Carinthia in St. Michael ob Bleiburg is one of the largest production plants of the MAHLE group. As shown in the picture above around 2500 people are working there.
The plant in St. Michael ob Bleiburg is producing:

- Fuel filters
- Oil filter modules
- Air intake module and cylinder heads
- Spin on filters
- Air-filter elements and fluid-filter elements

The plant in St. Micheal ob Bleiburg is divided in several segments, which are producing the above mentioned products and their components. The optimization described in this thesis mainly focuses on segment 15 as well as partly on segment 7. The involvement of segment 7 is needed because the disposal system also disposals finished goods of this segment.
Segment 15 is assembling plastic oil filter modules as well as producing some of its components.
Due to the size of the plant in St. Michael ob Bleiburg one segment is nearly as big as some other plants of the MAHLE group. Therefore one segment in St. Michael is doing nearly the same revenue of another plant of MAHLE.

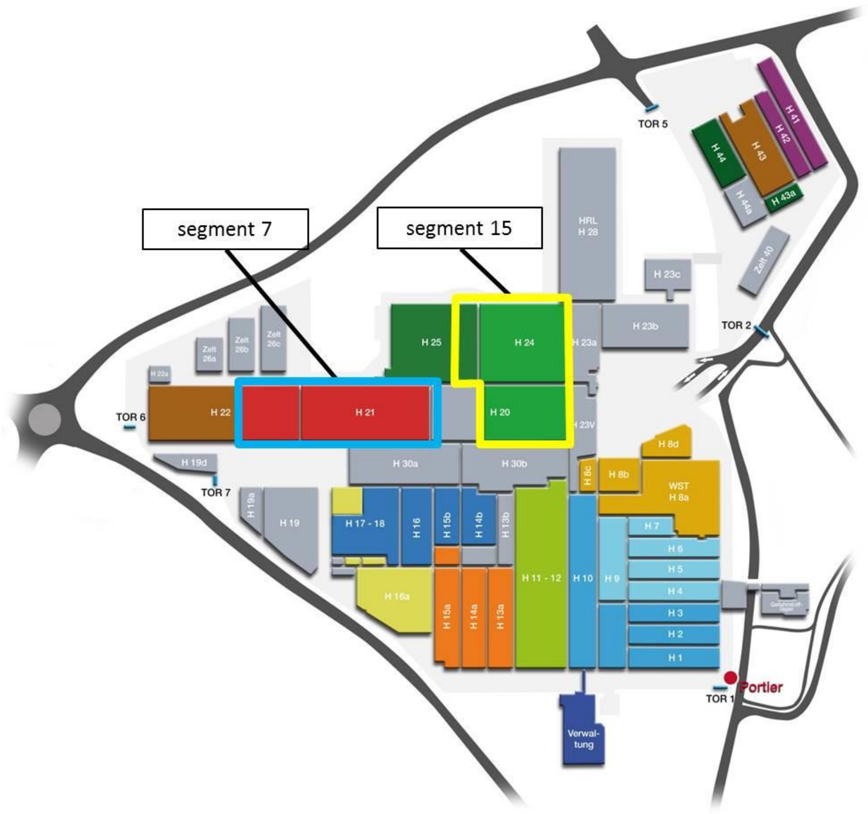

Figure 1-2: Allocation of the different segments on the plant

Figure 1-2 is showing where segment seven and fifteen are located at the plant in St. Michael ob Bleiburg. Segment fifteen is producing plastic oil filter modules. These modules are produced in a three shifts per day model for customers worldwide.

2 Introduction

The company MAHLE Filtersysteme Austria with its Austrian headquarter in St. Michael ob Bleiburg is part of MAHLE GmbH with its international headquarter in Stuttgart. MAHLE is a reknown worldwide supplier of the automotive industry.

2.1 Starting situation

The company in St. Michael is developing and introducing new processes and standards for supply and disposal of their production lines. These new processes and standards will be used as benchmarks for other MAHLE production units. The historical growth led to bottlenecks in the supply and disposal of production lines. In the past the supply and disposal of production lines have been done with forklifts only. In addition using forklifts caused safety issues. Therefore the company decided to install trailer route systems at some production lines, due to the better efficiency of trailer route systems related to forklifts. Part of the improvement has been lost, as the introduction of these trailer route systems led to traffic jams and do not fulfil the defined cycle times, which is the starting situation of this thesis.

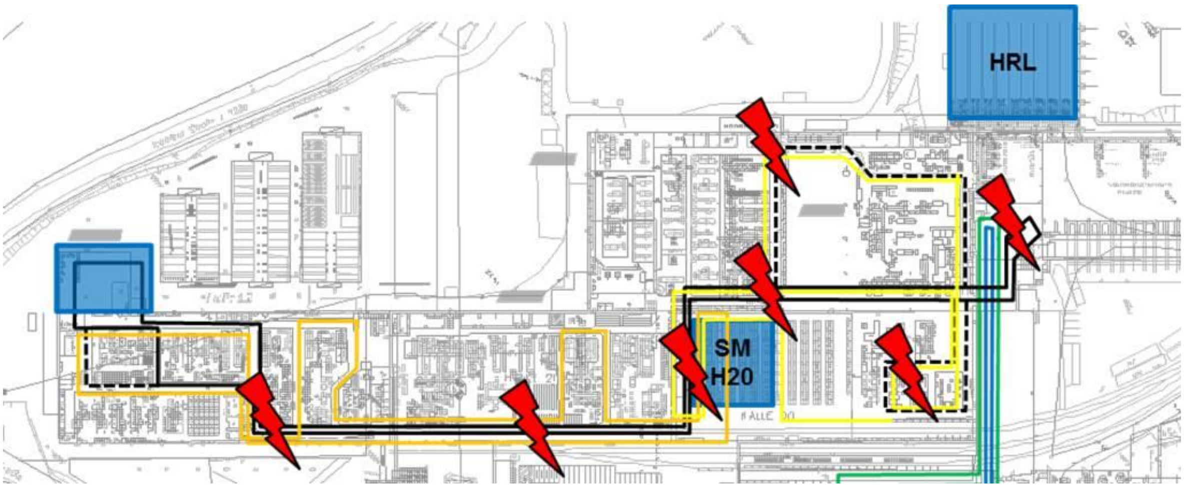

Figure 2-1: Overview of the critical places at MAHLE Filtersysteme

The vision of the company is to get away from forklifts and do the whole supply and disposal of materials for the production lines by trailer route systems. This change will significantly increase the efficiency of the supply and disposal of the production areas as well as improve the health and safety situation.

2.2 Target

Main target of this thesis is to optimize the current supply and disposal of production lines. This is split into several sub topics.

- Increase the utilization capacity and the efficiency of the used trailer route systems
- Elimination of waste (e.g. time, movement,…) considering Lean Management methods at MAHLE Filtersystems Austria GmbH
- Set new standards regarding standardisation, safety and work simplification

In order to reach that target it is needed to analyse the ongoing processes during the supply and disposal of production lines and especially highlight waste during these processes. Therefore a process definition, following the guidelines of Lean Management methods and its derivatives is needed to be done. Afterwards a weakness analysis is needed to be done in an academic way.
An additional point of this thesis is to evaluate the maximum capacity of the trailer route system as well as to improve the efficiency by reducing waste and parallelize processes. Finally all theoretical improvements developed in this thesis are needed to be tested and compared with the starting situation. The tests of the new improved system are done to close the DMAIC cycle.
To reach that target it is needed to get support of the whole materials logistic team as well as support of the production teams at all involved segments mentioned in this thesis.

2.3 Procedure

This thesis is following the methodology of the principles of SIX SIGMA by using the DMAIC cycle (Define Measure Analyse Improve and Control) to solve the given problems. The DMAIC cycle is used to define processes and working steps at their sources. Furthermore DMAIC cycle is used to improve the processes and working steps by pointing out waste based on measurements and analysis.
The DMAIC cycle for this thesis is explained in the following general steps:

- Understanding the process (Define)
- Make an Is-Analyses and Is-Measurement of the processes (Measure)
- Evaluate the Is-Analyses and the Is-Measurement (Analyse)
- Analyse and draw the different trailer systems routes (Analyse)
- Create process flow charts (Analyse)
- Calculate the material streams (Analyse)
- Develop different solutions for improvement of the processes (Improve)

- Analyse and measure the solutions (Control)
- Test and compare the best solution with the measurement before (Control)

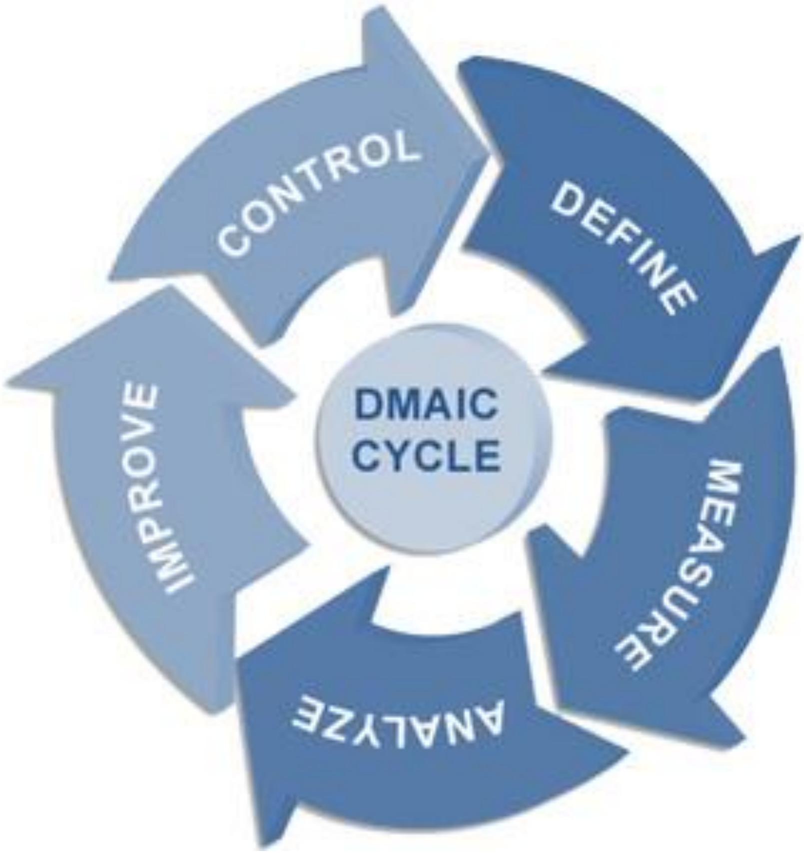

Figure 2-2: The DMAIC cycle

The is-analyses and is-measurement is following the criteria given by Arnold & Furman and Günther & Durchholz. To analyse the processes and working steps in a correct way, it is need do divide the whole process into sub-processes explained in detail in chapter 5.1.
The calculation of the material stream is following the criteria given by Günther & Durchholz and Arnold & Furman. Respecting these criteria an Excel-File is developed for this thesis to gain knowledge of the needed materials and its lead times.
In chapter 5.2 a weakness-analysis for the whole supply and disposal process is done following the guidelines of Peschges and Arnold & Furman.

3 Theoretical Background

3.1 Definition of logistic

In general logistic processes need to follow one flow. Nowadays this is often performed but in many companies it is not working well. One part of this thesis is to improve such flow of material and information. (Hertel, et al., 2011)
All activities with materials belonging to logistic are space and time related. Furthermore the amount -, the size - and the properties of goods are main points in defining logistic systems. Other very important points are, how the goods are planned, controlled and realised in this flow, to satisfier a previous defined deadline of the customer. In this thesis lead times are defined as the time material is ordered at the line until it is supplied to the line.
Logistic is an application-oriented science. It is analysing and modelling the flow of goods in a time and space oriented system and delivers solutions for design and implementation of new networks. (Hertel, et al., 2011)
Requirements to logistic are delivering the right product, at the right place, with the right properties with a minimum of costs to the right customer in right time. (Hertel, et al., 2011)
In literature, there are also other definitions like those that make a life time oriented logistic or service oriented logistic available, but those are not going to be explained furthermore in this thesis.
To optimize logistic processes it is needed to have a clear and well-structured material provision plan. This plan needs to include combinations of parts and its storage data as well as an amount of pieces and a working plan of the involved lines. Such a plan is needed to define the way of working as well as to control the complexity and flexibility. (Klug, 2010)
For the production of oil filter elements in segment 15 some of those processes are happening in house.
Exemplary the modified bill of material for an OF 206 is taken. This bill of material is showing the parts delivered by suppliers and parts produced in house. Suppliers are delivering all the red marked parts and all green marked parts are produced in house. As an example for the cover of the OF 206 only the granulate needs to be delivered. All other working steps are done in house of MAHLE Filtersysteme. This thesis is mainly focusing on the supply and the disposal of the needed materials for segment 15. These steps will be explained in chapter 4.2.

Table 3-1: modified bill of material

Material number	Used amount	Supplied by trailer system
70377285	2	X
70553337	1	X
70568558	1	X
70377284	1	X
70553181	1	X
70553176	1	X
70553514	5	X
70577461	1	X
70550127	1	
70553061	1	
70553056	4	X
70553047	1	X
70011197	1	
72352065	1	X
70553791	1	X
70553794	3	X

To plan a well working logistic system it is needed to get an amount of data out of many different sources. Figure 3-1: Sources of information for logistic planning Figure 3-1 is showing the different sources of logistic data.

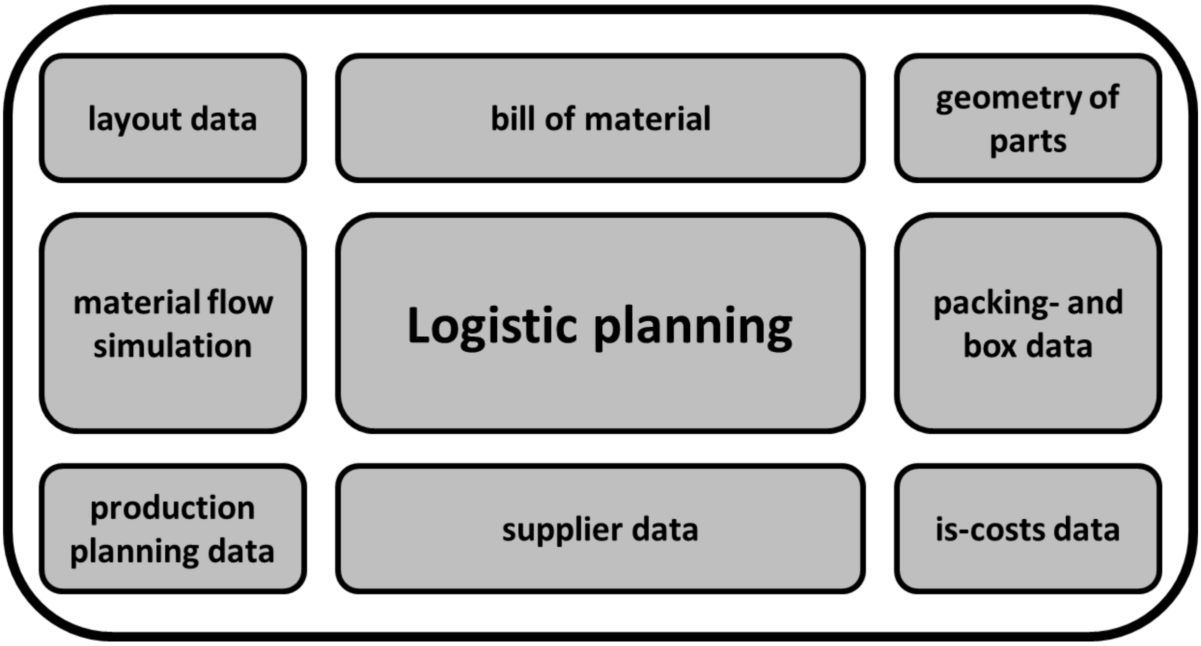

Figure 3-1: Sources of information for logistic planning (Klug, 2010)

A logistic data warehouse is the best solution for optimizing such processes, it contains information about goods needed per day, parts needed per day, line output per day, planed set up times and information about the needed parts. A very common practical problem of such a logistic data warehouse system is the feed of data into the system as well as the data file formats. In case of MAHLE

Filtersysteme every department has its own standalone data management with no or limited access for other departments. Therefore the logistic department is not able to access production data. This problem could be reduced by using logistic data warehouse saving all data in the same format in a central place, access to everybody who needs. The data stored in a logistic data warehouse are processed and structured that the relevant can be easily accessed. (Klug, 2010)

3.2 Supply Chain Management

The definition of Supply Chain Management is wide spread theoretically and practically. In literature Supply Chain Management sometimes even includes marketing. (Hertel, et al., 2011)
The three main different types of Supply Chain Management are: (Hertel, et al., 2011)

- Supply Chain Management as value-added process
- Supply Chain Management as group of companies
- Supply Chain Management as corporate organisation

In this thesis only Supply Chain Management as value-added process is explained in more detail, as this is the Supply Chain Management MAHLE Filtersysteme is dealing with.
Supply Chain Management as a value-added process starts with sourcing of row material and ends at the customer. It includes logistic processes, information flows as well as customer oriented activities. (Hertel, et al., 2011), (Gudehus, 2010)
Supply Chain Management is going to be more and more important in the whole automotive industry and its suppliers. Reasons for the importance of Supply Chain Management are for example reduction of the in-house productions, increased quality requirements and cost reductions. (Göpfert, et al., 2012)
In 2010 the seven most popular steps in Supply Chain Management were: (Göpfert, et al., 2012)

- Usage of the same data format
- Automated information flow between customer and supplier
- Transfer of information related to forecasts
- Implementation of a pull oriented production and distribution
- Usage of same specific carriers for goods between companies and suppliers
- Transfer of the quality responsibility to the suppliers
- Transfer of the distribution responsibility and ownership at the production site

In general it can be differentiated between Push-oriented and Pull-oriented Supply Chain Relations between customer and supplier, where currently the tendency is more towards Pull-oriented Supply Chain relationships. (Göpfert, et al., 2012)
Automated data flow between supplier and car manufacturer is going to lead in 65 percentages of the 470 interviewed suppliers to a decrease of costs, because the transaction processes are omitted. The method of planning together contains company across development and setting of prospective purchase order quantity as well as size of production and capacity between car manufacturer and supplier. In most cases the supplier gains additional information about the prospective needs of the manufacturer. With this information the supplier is able to plan the size of production and inform the manufacturer about bottlenecks or delivery difficulties. (Göpfert, et al., 2012)
One action in Supply Chain Management which is going to lead to success in future is:

- Decrease of costs in transport facilities

Transport cost reduction can be done by a better utilization of space in transport vehicles between supplier and customers, especially in Build-to-Order relations. One solution is to bundle those transports. (Göpfert, et al., 2012)
MAHLE Filtersysteme Austria also got a Build-to-Order department.
The pull oriented production plants are mostly managed centralized where the production and the logistic is planned in predefined value oriented processes. (Göpfert, et al., 2012)

3.3 Material flow logistic

In well working production systems a flow should be visible. For this production needs be divided in different steps. These steps should create a flow through the whole production lines. This flow can be divided in additional sub-steps, which needs to be well organized and structured to gain an optimum out of it. (Arnold, et al., 2007)
The technical main steps are:

- Machining
- Assembling
- Testing
- Handling
- Conveying
- Storing
- Collecting
- Distributing
- Sorting
- Packing

For the analysis of the capacity of the trailer route system some of those steps need to be separated into different sub-steps. Especially the steps handling and conveying need to be divided further, to gain analysable data out of it. For that there were following sub-steps introduced:

- Handling by the line
- Picking in the supermarket
- Waiting time
- Drive time
- Time for replying finished goods
- Time for binding finished goods with tape

With these sub-steps and the needed time to fulfil them a process profile is deviated.
There are two types of structures available in the material flow theory. One is the clear line followed system, where only one source and one sink are available and every process is done after the other. The other one is the more complex network structure. In the network structure system there are more sources and sinks available and a complex network of processes with different routes of the material shifted through the production. In that system different processes could be done simultaneous and serial. In the case of MAHLE Filtersysteme it is

a complex network of the production, with many simultaneous and serial working processes. (Arnold, et al., 2007)
Material flow theory tries to display real complex working processes and steps in strongly simplified models to gain solutions and optimizations. (Arnold, et al., 2007)

3.4 Push and Pull

Push is Make-to-Stock , pull is Built-to-Order, which means that a push oriented production system needs more space for storing the finished products. Pull oriented production systems are very flexible and able to react quickly on demand changes. Pull oriented systems are controlled and managed decentralized. The assembly- and logistic processes start with the start of production. In contrast to pull oriented systems, push oriented systems are central managed and controlled. Pull oriented systems create the need of material when the parts are used for production, which means after the material is used another one is ordered. MAHLE Filtersysteme is using a pull oriented system for its production lines. (Göpfert, et al., 2012)

3.5 Internal Transport Systems

The choice of an internal transport system is influenced by different factors like how goods are needed to be conveyed, frequency and amount of goods. By these parameters most companies create their own internal transport system. Nowadays automotive industry is using more and more trailer route systems. Compared to forklifts trailer route systems are less flexible but much saver and can convey more material by one drive. (Klug, 2010)

3.5.1 Forklift transport

Transporting goods by forklifts is one of the most flexible systems, but forklift transports are having a high risk of safety during transporting and are limited by maximum height. If a forklift is carrying two or three pallets on top of each other, than the view of the driver is heavily affected by the pallets. This leads to high safety risks due to limited visible zones. (Klug, 2010)

Figure 3-2: Unloaded and loaded forklift

Forklifts tasks are to grab, lift, transport and drop goods on specified places in a production plant. Another main usage of forklift is in the loading and unloading of heavy goods vehicles. There are different kinds of powertrain systems for forklifts available, the company MAHLE Filtersysteme is using electrical driven forklifts in the production halls. (Klug, 2010)
Forklifts are limited by the size and weight of the material that should be moved. Another negative point is the limited tray capacity a forklift has. The efficiency of forklifts decreases dramatically by increasing distances a forklift has to drive and increasing transport volumes. This leads for new demands of tray transporting systems. (Klug, 2010)

3.5.2 Trailer system transport

Due to the negative effects of forklift transports more and more companies are going to substitute forklifts by trailer route systems where appropriate. In comparison to forklifts a trailer route system is able to transport more material per drive and the visibility of the driver is not effected by the transported goods. Additional advantages of trailer route system are a continuous and levelled material flows as it can defined cycle times. Using trailer route systems also has positive effects on the internal bullwhip effect. (Klug, 2010)

Figure 3-3: Disposal- and supply trailer route system

Those trailer systems consist of a number of trailers for carrying goods and a towing vehicle operated by driver. The trailers are built on steel frames with wheels and mostly a pneumatic lifting mechanism and a drawbar coupling for steering. Furthermore trailer transport systems are decreasing the number of drives for trays rapidly. Currently a trailer route system got space for four to five pallets where a forklift is limited to a maximum of three. Another very important point in comparison to forklifts is the reduction of needed lane width. These systems are also decreasing the costs per transported unit, because of the higher number of trays they can carry. The following parameters are needed to be taken into account when installing a trailer transport system: (Klug, 2010)

- Number of used trailer systems
- Definition of needed towing force and number of trailers per system
- Standardization of tray sizes and standardization of trailer sizes
- Definition of clear routes of supply and disposal trailers as well as preparing trailer bays
- Definition of cycle times

Trailer route system also need clear and visual prepared information systems for all employees, where trailer bays and cycle times are drawn. The routes need to be driven in a one-way system, that no accidents between trailer systems happen and a clear separation between employee sidewalk and trailer system road need to be installed. The efficiency increases dramatically by huge distances and the number of trays needed to be transported in comparison to forklifts. During the weakness analysis in chapter 4.4 improvements and weaknesses of the transport processes are highlighted. Chapter 6 is dealing with the improvements this thesis is delivering to the company and the results of those improvements are shown in chapter 7. (Klug, 2010)

3.5.3 Autonomy driving transport systems

Autonomy driven transports systems are conveyor systems with own drivetrains which are automatically steered and controlled. The requirements for such an autonomous system need a huge number of components, which are very expensive. For example sensors for position-fixing as well as information transfer systems to delegate those automotive systems and well organized infrastructure behind the system. (Klug, 2010)

3.6 The Kanban System

Kanban System is a steering system for production. Kanban is Japanese for card. This card includes the product, quantity per batch size, place of origin and destination of the product. Requirements for Kanban systems are a zero failure strategy, following Kanban guidelines and cycle times of supply must be ensured. (Günthner, et al., 2013)

There are three different ways to work with Kanban cards. The first one is the Kanban by view in this case the operator is visually checking the number of products at specified stopping places and reordering products if necessary. The second system provides the information electronically.

3.7 Lean Management

3.7.1 Toyota Production System

The Toyota Production System is more or less the source of Lean Management and Lean Thinking. TPS was introduced by the car manufacturer Toyota to react quicker and more flexible on market changes and gain competitive advantages out of it, especially compared to mass producing manufacturer. To create such a system it was needed to illustrate the waste during production. Therefore Toyota not just only searched for direct waste like material waste or rework. Toyota also looked for indirect waste like not needed waiting times or too high material stock. To face such waste Toyota accepted on the one hand side a total downtime of production. On the other side Toyota integrated the employees to show waste during production and to improve the processes, because an employee who daily works on products knows best about the production of a product. (Schäfer, 2015)

Toyota transferred the responsibility for the whole car to their employees. In relation to employees of a standard mass production company, Toyota's employees were more motivated and improved the processes, because they were allowed to work on a whole car and not just on a single part of the car. Another positive aspect was that the quality of their cars heavily increased after that step, because the employees felt responsible for their work. (Schäfer, 2015)

During the oil crisis in 1973 Toyota's profit was less affected, compared to all other car manufacturers. In 1990 the Massachusetts Institute of Technology introduced the term LEAN. (Schäfer, 2015)

In reality the developer of the term LEAN were Taiichi Ono and Shigeo Shingo after World War II in Japan. Those two set up a total new way of how to produce cars. In the Toyota Production System one main idea is the thinking about the realized problems and try to eliminate those problems in the future. To fulfil those requirements the whole company needs to understand the philosophy of LEAN. (Dickmann, 2009)

3.7.2 Lean Management focusing on wastage

The 1990 introduced term "LEAN" is developed today further and influences nearly all main departments of a company. It is called "Lean Management". Lean Management starts at the company and ends at the customer. It is executed in departments of development, production, maintenance as well as the administration. (Bär, et al., 2014)

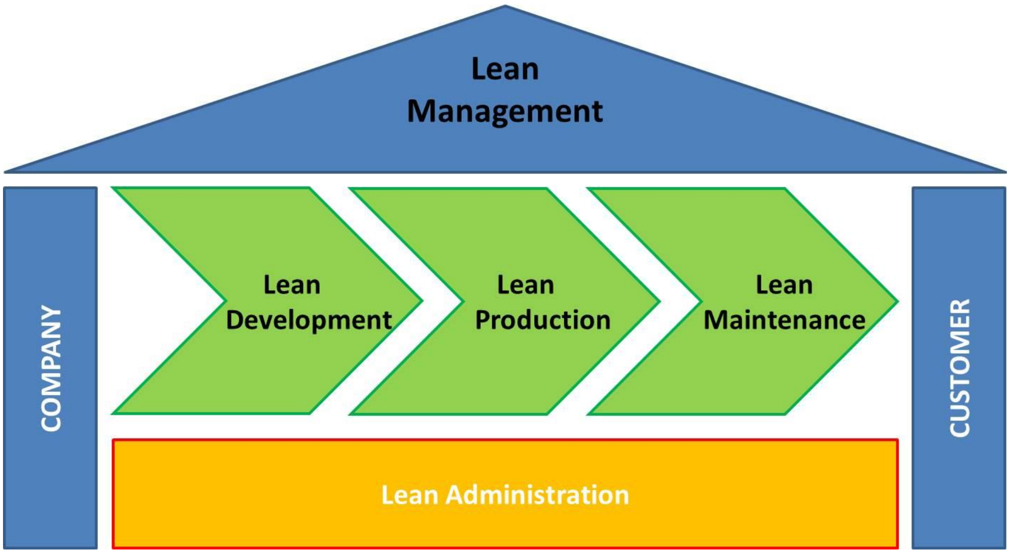

Figure 3-4: The house of LEAN Management (Bär, et al., 2014)

Lean Production was more or less the old part of "LEAN". Today it focuses on production processes. The main target of "LEAN" is to decrease waste and increase efficiency. Today customers heavily influence this management philosophy. For the term "WASTE" the term "MUDA" was introduced. (Bär, et al., 2014)

In this thesis Lean Management is going to be implemented for waste reduction and process organisations.

Generally Lean Management is difficult to interpret, because it is more than just a further developed version of the Toyota Production System it is more a whole philosophy and thinking. (Waurick, 2014)

As mentioned before this thesis is concentrating on LEAN topics like waste reduction, reduction of waiting times and creating a work- and process flow for the trailer system. One step to create such a well working process flow is to have a production system which is working with the PULL principle. The PULL principle is described in chapter 3.4.

Another main point of Lean Management is to gain a maximum of customer satisfaction with decreasing production costs by organizing the production system with the employees and around them. (Waurick, 2014)

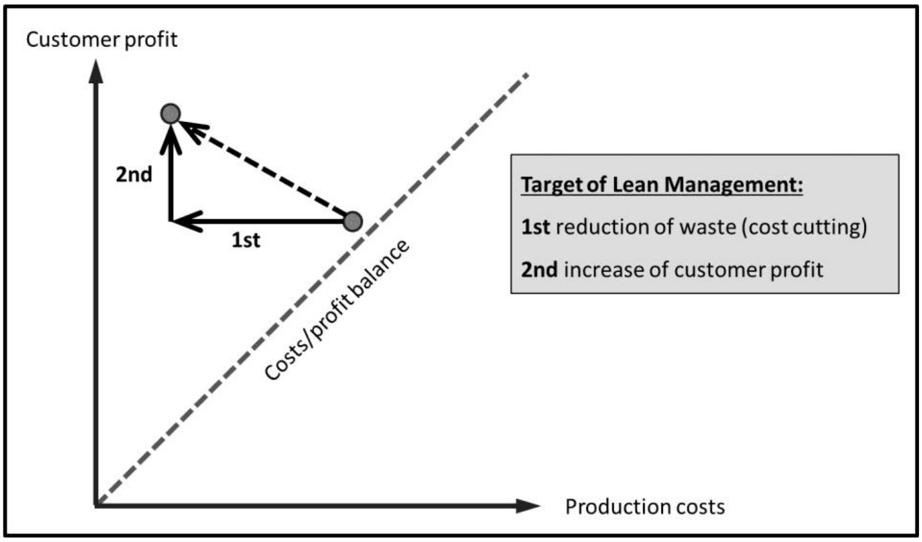

Figure 3-5: Target of LEAN Management (Waurick, 2014)

The core methods of LEAN Management are on one side the universal methods, which lead to constantly improvements. On the other side there are the project- and object oriented methods, these methods have a clear target which is in most cases temporary.

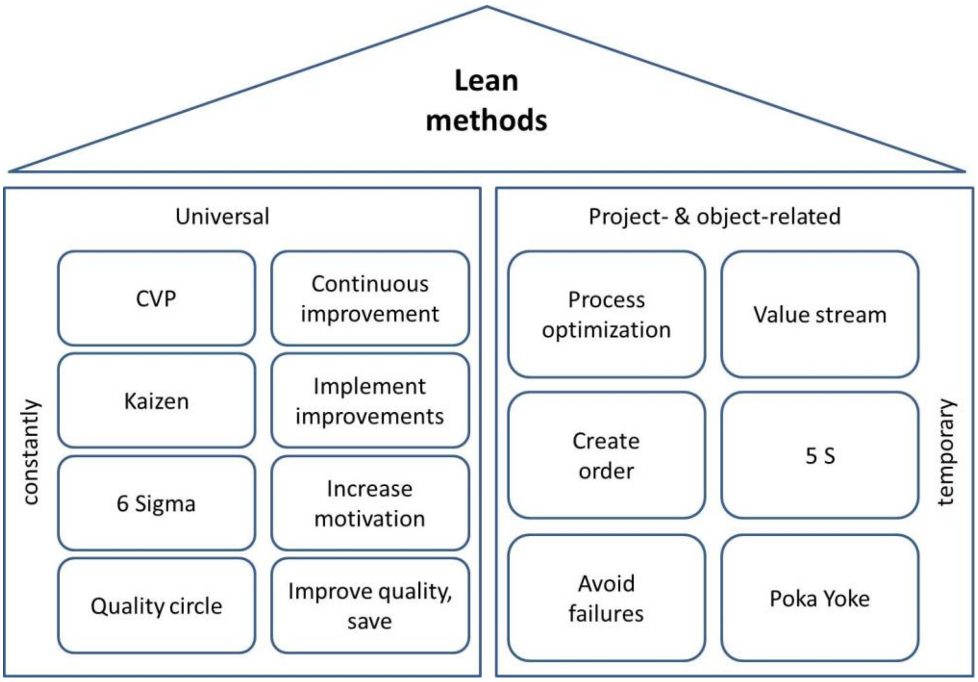

Figure 3-6: Methods of LEAN (Bär, et al., 2014)

For this thesis the relevant methods are the Continuous Improvement Process CIP, Kaizen, the Q-Circle, Value analysis, 5S and Poka Yoke.

Target of the Continuous Improvement Process are long term optimizations and improvements. The target of the process is strongly customer oriented. The procedure of the CIP is: Plan, Do, Check, Act.

3.7.2.1 MUDA, MURI and MURA

In Japan the usage of MUDA is used for unnecessary waste. MUDA is one of the three MU's which together describe how to reduce waste in the TPS: (Bär, et al., 2014)

- MURA means imbalance in case of productivity
- MURI means overloading in case of too much to do
- MUDA means waste of resources

MURA describes the loss of productivity by facing on the different processes during production, which are often not idealized and not optimized. Mechanical waiting times and downtimes of production machines are the most important points of MURA. Another point of MURA is process coordination and process optimization. (Bär, et al., 2014)
MURI describes the loss by facing on machine- and employee overloading. Downtimes of machines cannot be excluded, but can be minimized by the right usage of machines. Therefore the main point of MURI is to find the working intensity of machines where they are having the best productivity. Overload of employees is also not the right way, because if employees are challenged too much or need to work too hard the number of burnouts and the number of sick leaves are going to increase rapidly. (Bär, et al., 2014)
The last point MUDA is dealing with the case of wasting resources. There are seven points available: (Bär, et al., 2014), (Schäfer, 2015), (Göpfert, et al., 2012)

- Worthless working steps
- Unnecessary movements
- Unnecessary transports
- Waiting time and idle times
- Over productions
- Unsuitable stocks
- Mistakes and reworks

For this thesis the points unnecessary movements, unnecessary transports, waiting time and idle times, unsuitable stocks and mistakes and reworks are needed to be explained in more detail.
Unnecessary movements in case of trailer systems and its drivers are unneeded ways of the whole trailer system or ways trailer system drivers needs to walk for nothing productive. Those ways and walks are mostly unproductive and are unnecessary. Henry Ford in 1913 faced this problem and implemented in his company a self-moving assembly line, which brought the work to the employees.

He faced this problem by observing his employees. By installing a self-moving production line he decreased the distances an employee had to walk and reduced the movements they needed to carry out their work. Another positive effect was that the cycle times per product were decreased. Toyota developed that idea further and discovered that the process of looking for a tool and component as well is a waste. They introduced a cleaned up working place. In such cleaned up working places every tool has its own place. Therefore it is easy to find the right tool and report if some tools are missing. Also in production lines such optimizations have taken place, for example the semi-circular working place for improved handling. (Schäfer, 2015)
Waste through not needed transports is the next point that is going to be explained. This point is mainly dealing with not needed transports and cycle times. Cycle times were already a problem in 1930 where the traveling salesman problem was faced up. This problem is dealing with the optimized route for delivering goods to specified places and the returning. That was a combinatorial problem between operation research and theoretical informatics. There were many different solutions for that problem developed, but Toyota found the best solution. Toyota's solution was to only deliver if empty trays are available. With that solution the transport costs were decreased by 30 percent and the on time delivery was increased by 25 percent. This system was more or less derivable from the old known milkman system, just deliver a new bottle of milk if an empty was placed. Today some companies are using this system by including their suppliers on their own production plants to reduce the delivery costs and delivery ways. In case of MAHLE Filtersysteme the system of Toyota is performed but needs to be improved. (Schäfer, 2015)
The next point is waiting time and idle time of a trailer system driver. For that it needs to be mentioned that waiting time and idle time in the factory of MAHLE Filtersysteme is a main source of loss of capacity. It is approximately 12 percentages of a work day of a trailer route system driver.
Waiting time and idle time of a production line is also mentioned in different Lean Management books but for this thesis waiting time and idle time of a trailer system driver and the system mainly needs to be faced. As a practical example, if a trailer system driver does not deliver a box for final goods on time the whole line in the production needs to be shut down because the line workers do not have enough storage place. (Schäfer, 2015)
This waiting times and idle time are caused by traffic jams during their drives and not utilizing the full transport capacity. One part of this thesis is to create a working profile of a trailer system operator.
Waste by unsuitable stocks is another point of this thesis to find a right mix of components on stock and components on line. Components on stock create high costs for a company, because it is occupied space. On the other hand every company needs a particular number of components on stock to deliver it on time directly to the line. For a well working production system those inventory ranges at a production line needs to be up to date. (Schäfer, 2015)
The last point is mistakes and rework. Mistakes and rework are also main parts of this thesis. Mistakes and rework cause costs in production lines like MAHLE Filtersysteme has, if a line is needs to be shut down due to wrong material delivered in case of MUDA. This sort of waste can be eliminated by the four principles of Jidoka. Those four principles include going to the source, Andon

tables, standardisations and Poka-Yoke. Those principles are going to be explained more in detail in chapter 6.9.
Another important tool to face the wasting points of MUDA is the tool of Lean Thinking.

3.7.3 LEAN Thinking

Core idea of LEAN Thinking is to maximize the customer value by reducing the loss of productivity especially through avoiding waste. Target of the philosophy of LEAN Thinking is to optimize the customer value with optimized resource usage.

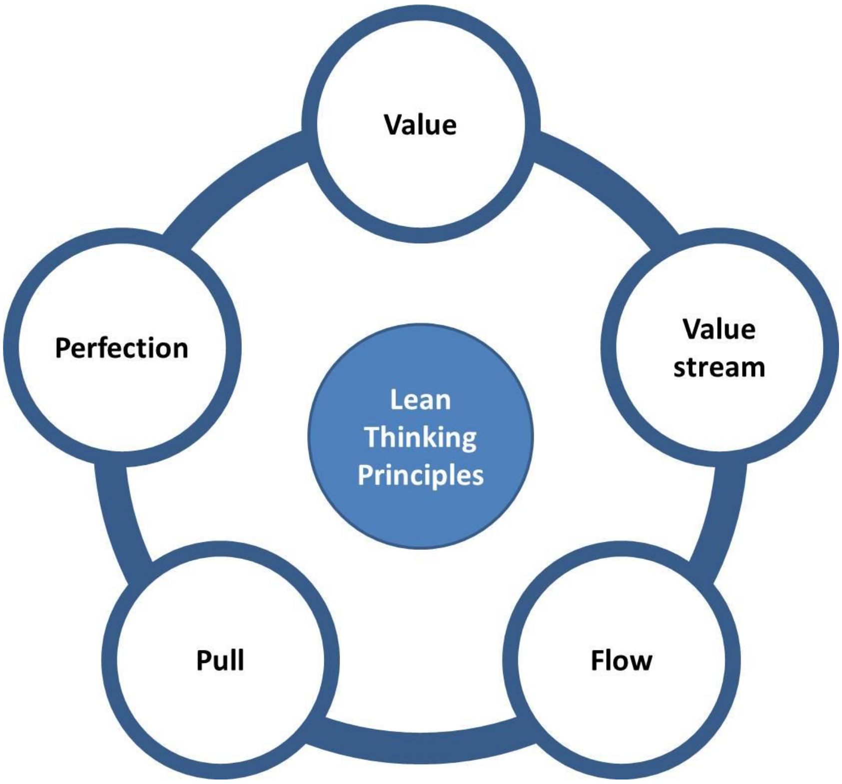

Figure 3-7: Principles of LEAN Thinking (Bär, et al., 2014)

3.8 Build to Order

Build-to-Order means wait until customer orders, than build and decrease by the usage of this strategy the costs of storing products on factory plants. The difficulty by the build-to-order strategy is to build products in the allowed time of the customer. The problem with the availability of products is not that high by build-to-forecast, but this strategy needs difficult calculation models or good sales volume forecasts. (Göpfert, et al., 2012)
Main target of a Build-to-Order strategy is to increase market shares with increasing profits related to customer satisfaction. Another difficulty in the build-to-order strategy is that there is no flattening factor alpha like in the build-to-forecast strategy. The alpha factor flattens the theoretical amount of production. All previous mentioned points lead to the need of a very flexible

Supply Chain. For a flexible Supply Chain the following points need to be fulfilled: (Klug, 2010)

- Flexible belt loads of different assembly lines
- Reduction of throughput time
- Availability of capacity reserves
- Demand changes until start of production by fulfilling deadlines
- Flexible value added structures in combination with well-organized logistic structures

4 Problem analysis

4.1 Description of the problem and impressions

The first impression of the system is, it is working, but there is no clear and structured material- and information flow. The supply trailer system drivers are allowed to order as many small load carriers (SLC) as they like. The material order cards at the lines are not kept up to date. At shift start the driver of the disposal trailer system have very little information about the production plan during their shift. The number of finished good boxes supplied to the lines is mainly based on the long term experience of the disposal system drivers. One major problem is that a not experienced driver do not know the type and number of boxes are needed at the line. Therefore it is needed to set up a standardized working procedure and increase the information flow.
To become more familiar with the problems a weakness-analysis in chapter 5.2 is describing the problems and weaknesses of the system. The weakness-analysis is following the criteria set by Günthner & Durchholz. The weaknesses are needed to be divided in technical weaknesses, human weaknesses or organisational weaknesses.

4.2 Supply trailer route systems

These trailer route trains supply production lines with needed materials for producing goods. In case of MAHLE Filtersysteme these supply trains in segment 15 consist of a tractor unit and four e-typed frames.
The tractor unit is lifting the e-typed frames by hydraulic pressure, so the trolleys on the frames do not touch the ground and can be towed. On the tractor unit a fixing mechanism is installed so the lifted frames can be fixed in the position. That decreases the wear of the hydraulic system. The e-typed frames are used to transport trolleys of SLCs or storing trolleys for single or multiple SLCs. On those storing trolleys the drivers stores SLCs in different sizes with needed material for each production line. Table 4-1 is showing the dimensions of the most used SLCs for transporting material.

Table 4-1: Classification of SLCs

Name of SLC	Length [mm]	Width [mm]	Height [mm]
3215	297	198	147,5
4315	396	297	147,5
6415	594	396	147,5
6280	594	396	280

Figure 4-1: SLC typed 6280

Figure 4-1 is showing a SLC typed 6280 which are the biggest SLCs used at MAHLE Filtersysteme to move, store and transport materials to the production lines. These SLCs are normed by the VDA to organize an exchange of SLCs between different companies. Many other companies also are using those SLCs to move, buffer or store different materials. (Klug, 2010)

Figure 4-2: Tractor unit of a trailer route system

Figure 4-2 is showing one tractor unit of the trailer route systems used at MAHLE Filtersysteme. One of the main advantages of those tractor units is that the driver has a clear view in the direction he/she is driving. Comparing a trailer route system with a forklift, the driver is always moving in one direction and does not reverse gear.

Figure 4-3: E-typed trailer of the system

Figure 4-3 is showing an e-typed frame to transport trolleys of storing trolleys showed in Figure 4-4. At the supply trains four of those frames are installed and at the disposal trains were five installed.

Figure 4-4: Supply trolley of the trailer route system

Figure 4-5 is showing a ready assembled supply trailer route system. On the second and third e-typed frames there are picked SLCs loaded on levelled trolleys, which are positioned on an e-typed frame.

Figure 4-5: Complete assembled supply train

Theoretically these systems need to run on defined cycle times and bring material just in time to the production lines. (Günthner, et al., 2013) (Göpfert, et al., 2012)

Practically such defined cycle times are hard to fulfil, because there will always be parameters that disturb those times. For example a down time of one production line during the shift at a not previously known time.

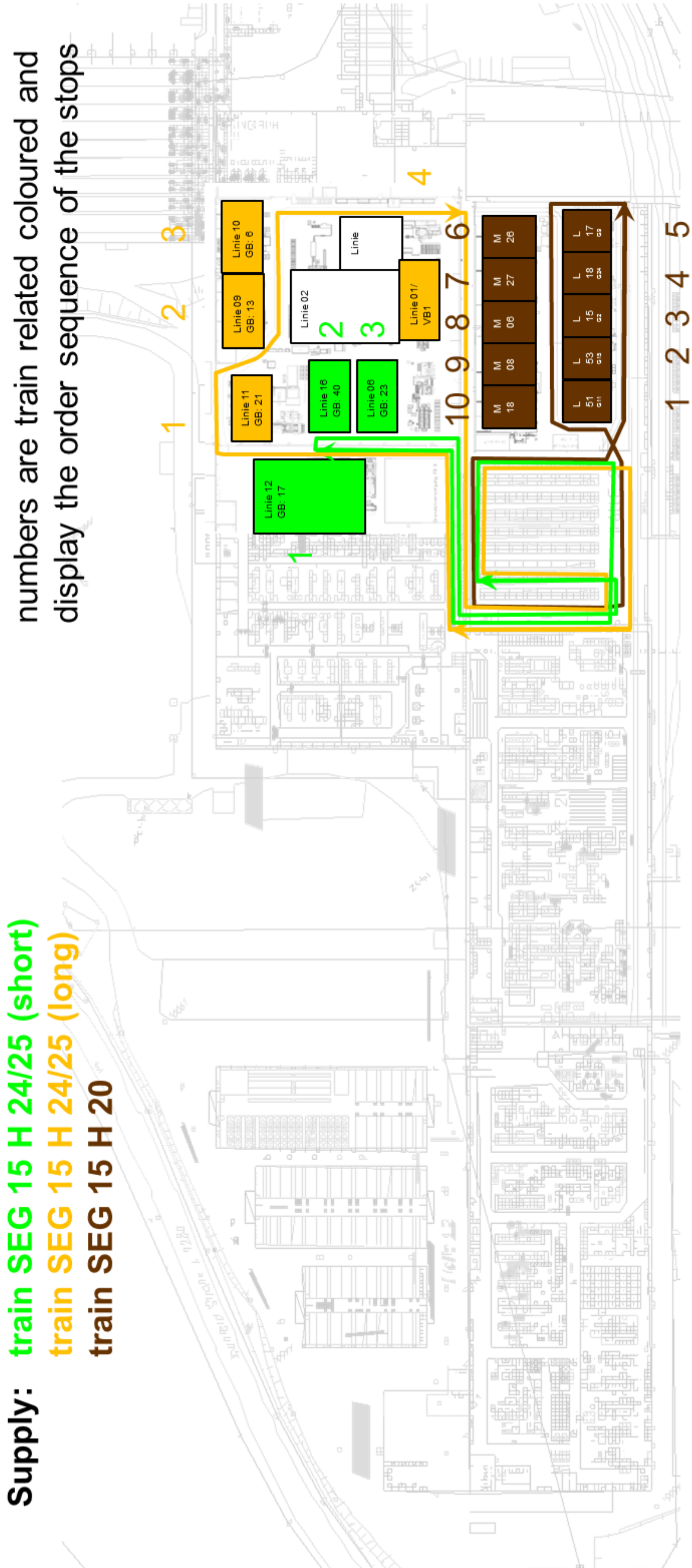

Figure 4-6: Supply routes of segment 15

Figure 4-6 is showing the routes of the supply trains in the halls of segment 15. Every supply route has a linkage to the SAP database of the logistic team so every route got a colour to make them better visible for this thesis. The starting situation was three trains running on a cycle time of thirty minutes. The orange route was suppling production lines numbered by 01, 09, 10 and some parts for line 11. This route was not reaching high capacity what lead to a rethinking of the route plans in chapter 6.2.3.
The brown route is the supply route for production hall twenty in segment 15. The trailer drivers of that route are very busy during their shifts because a huge amount of material is needed there as well as a special supply trolley. for heat exchangers is needed to load for two lines. Production line 17 and 18 can be seen as high runner lines. In this thesis high runner lines are defined to produce more than 1000 finished oil filter modules per shift.
The last route in segment 15 is the green one. That route had two high runner production lines to supply and one line, which was running just during one of the three-shifts.

4.3 Disposal trailer route system

The disposal trailer route system is influenced by segment 7 as well as by segment 15. Therefore, segment 7 influences the data and the processes of the disposal trains. The disposal trailer trains consist of a tractor unit and five e-typed frames.

Figure 4-7: Disposal trailer route system

Figure 4-7 is showing a disposal train loaded with finished storing boxes for produced goods.

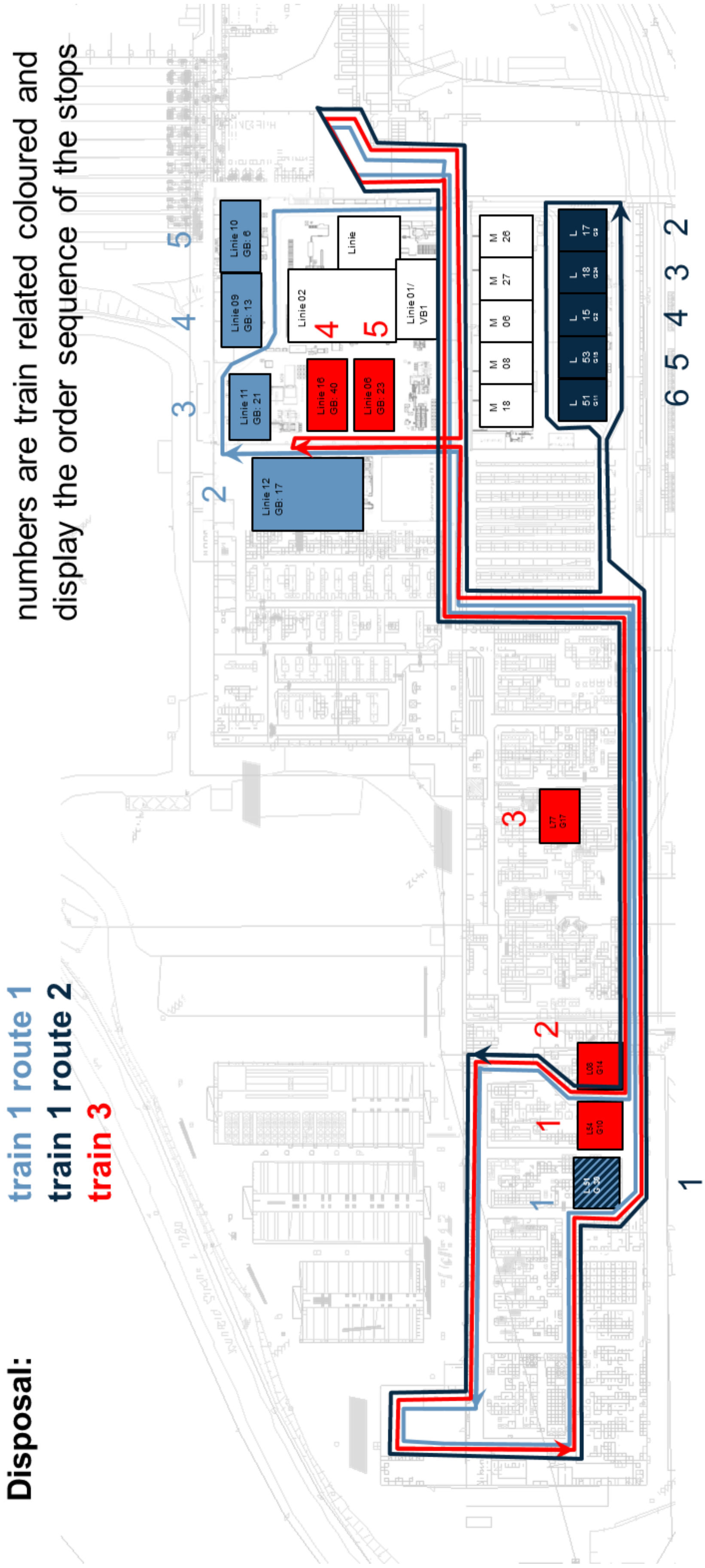

Figure 4-8: Disposal routes of segment 7 and 15

Figure 4-8 is showing the routes of the disposal trains in the halls of MAHLE Filtersysteme. For the disposal system no SAP data is available to steer the system or control it. That is also going to be a point in the weakness analysis in chapter 5.2. Chapter 6.4 is explaining a concept solution to improve the disposal system by SAP and information management.

4.4 Is-Measurement

The is-analysis and is-measurement of the system is needed to highlight the waste of the system during the drives. The is-measurement is following the guidelines given by Arnold & Furmans and the sub-steps are defined during the operating time at MAHLE Filtersysteme. Target is to create a valuable time table of the drives the trailer route drivers did. To create such a time table the paper of Figure 4-9 needs to be filled with measured times.

list number.:		start time:		end time:	
route:		notes:			
empties:		lap time:			

line nr.:	SLCs	drive time	pick time	handling	binding	reply	waiting time	line stand	walking	notes

Figure 4-9: Paper layout for is-measurement

Figure 4-9 is showing the sub-steps of the measurement table used for the second step of the DMAIC-cycle. On the top of the paper, it is needed to write the pick-list number to allocate the list afterwards in the SAP-System. (Arnold, et al., 2007)

The measurement papers also consider of the correct route number and the number of SLCs moved by one ride. On the right side of the paper the starting- and the end times of one lap are noted. These times are necessary for one part of the analysis of the is-measurement in chapter 4.5. The eleven columns and their properties are going to be explained more in detail above: (Arnold, et al., 2007)

- Line number: The line number is needed to identify the production line after the measurement in the segment. In the field of observation, thirteen production lines of the segment 15 are involved. The lines have an output between 450 parts per shift and 2800 parts per shift. The difficulty of a product levelling is going to be analysed more in detail in chapter 5.2.
- SLCs: In that column the number of SLCs are noted. On the paper is also noted the number of full trolleys with heat exchangers moved during the measurement.
- Drive time: That column is for the whole drive time a trailer route system had on one lap. For the observation of this thesis it is not necessary to dived the drive time furthermore in acceleration, driving and braking. (Arnold, et al., 2007), (Günthner, et al., 2013)
- Pick time: The time a trailer route system driver needs in the supermarket to unload empty SLCs and place them on various collecting points. The other part of the column picking time is for the uploading of full SLCs on a trolley.
- Handling time: This time includes the time a trailer route system driver needs at a production line to load the filling channels on a line with full SLCs as well as to unload the return channels of SLCs.
- Binding time: The column binding time is mostly mentionable for the disposal trailer route system drivers. The binding of finished product trolleys is done in the segment 15 always by the trailer route system driver.
- Reply time: The part of the needed time to reply a finished product trolley to the SAP-system and create a transport order to the high-bay warehouse.
- Waiting time: This is one main part of this thesis, because waiting time is part of MUDA in the LEAN philosophy and more or less easy to eliminate

by introducing rules and standards to employees and their working places. (Klug, 2010)

- Line stands: If a line is not working or being on a set-up process
- Walking: The column walking is only filled out if a trailer route system driver needs to walk huge distances between operating location and the trailer route system or the provided material.
- Notes: The last column on the paper is for special actions or notes that needed to be analysed chapter 5.2.

With those eleven columns it is possible to create a time study and allocate waste during the process of a trailer route system driver.

4.5 Is-Analysis

The is-analysis of the thesis focuses on the one side on the supply and on the other side of the disposal of finished goods. Figure 4-6 is showing the supply routes at the plant and Figure 4-8 the disposal routes.
To evaluate the recorded times on the papers it is needed to create pie charts. The pie charts for the supply are also showing the times of each measured sub-process for one shift.

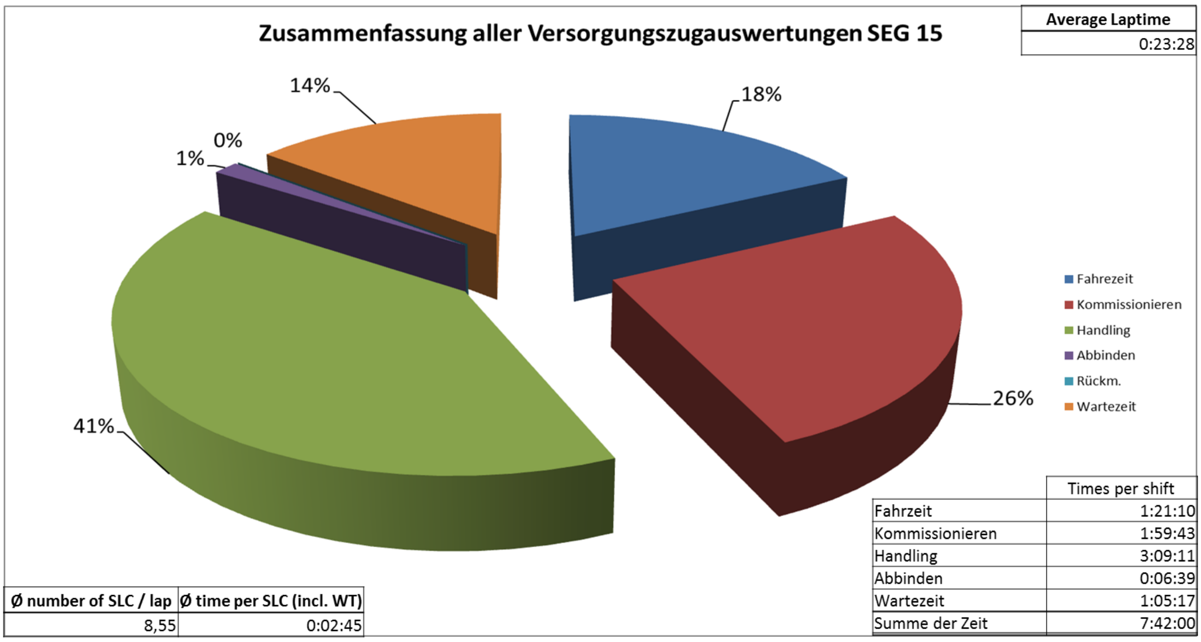

Figure 4-10: Evaluation summary of all supply routes

Figure 4-10 is showing the summary of the evaluation of the times measured for the supply routes in segment 15. For that thesis it is also needed to analyse every single supply route on its own.
The analysis shows that the average number of transported SLCs for production hall twenty is 10,3 SLCs per lap. The short train route for production hall 24/25 is just transporting 6,3 SLCs per lap. That low number is one indication for waste during the supply on this line. If production line twelve is not running, the short supply system is running on a cycle time of twenty minutes. Therefore every third lap is an unloaded drive. These unloaded drives are one fact for the variant of the combination of the supply routes two and three. Chapter 6.2.3 is going to explain that variant more in detail.
Another fact for a rethink of the two supply lines of hall 24/25 is that the supply system for production hall twenty is transporting during the is-analysis nearly twice as much material as each supply trailer system for hall 24/25.
Figure 4-10 is also showing the average number of transported SLCs per lap for all 3 supply routes. This number is an important indicator for the rethinking of the layout The number of 8,55 SLCs is quite low for the possibility to transport an amount of 24 SLCs typed 6280 up to an amount of 192 SLCs typed 3215 every lap.

Waiting time is the indicator for waste during the analysis. The drivers are waiting more than one hour per shift, which is pure waste of time considering the LEAN Management methods of chapter 3.7.
Waiting time and unloaded drives are clearly related to two of the three MU's of chapter 3.7.2.1. They describe the unneeded waste during the workflow and its processes in case of Lean Management. (Bär, et al., 2014)
Reasons for waiting times are jams with other trailer route systems, forklifts blockings of the routes or just no space to park the system on pre-defined stopping stations. The pre-defined stopping stations where the trailer route systems are allowed to stop are explained more in detail in chapter 6.8. (Klug, 2010)

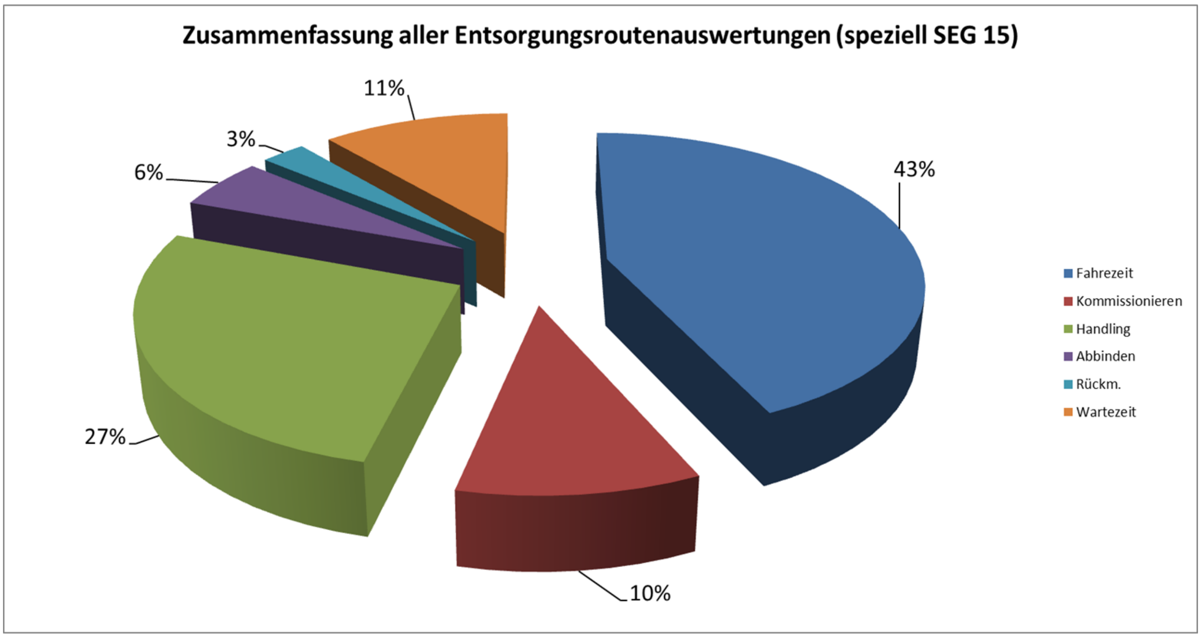

Figure 4-11: Summary of all disposal routes

In Figure 4-11 the analysis of the disposal process is visible. Two main points are the long drive time and once more the waiting time of 11 percentages what are nearly 51 minutes of a shift. The point of long drive time is going to be explained more in detail in chapter 5.2.
After the analysis of the collected data the average capacity of the disposal trailer route system were 84 percentage. There is one big difference between the two shifts. Shift A was doing the disposal with two trailer route system drivers that lead to a capacity of 80 percentage. In shift B the disposal was done by one driver, which lead to a capacity of 97 percentage.
The disposal trailer route system drivers also needs to bind some finished good boxes or cover open gaps with tape. Furthermore the drivers needs to reply the finished goods and make a transport order for the trolley. The binding and replying of each box needs between fifteen seconds and one and a half minute, if the binding and replying is not working perfectly.

4.6 Inventory Range

The inventory ranges in companies need to be that big that a production line always has enough material to produce and do not need to stop. To guarantee no stop of the production lines the inventory puffers at a line needs to be bigger as the replacement time of material. To lower the inventory costs and the costs at the production places these buffer places need to be as small as possible. The inventory ranges in segment 15 are calculated for a supply trailer route system with an average lap time of thirty minutes. Therefore, the inventory ranges at every line needs to be for one hour and one SLC. One problem is that those numbers for needed SLCs were old and not recalculated to new throughput times of modernized production lines. That can lead to an empty SLC channel at a production line because the trailer route system driver do not have enough SLCs on his/her trolley. For this thesis it is needed to recalculate the inventory ranges of segment fifteen. (Günthner, et al., 2013) (Klug, 2010)

To recalculate the inventory ranges an Excel-file is developed, which is going to be explained in chapter 6.5. After evaluating the Excel file the lowest inventory range was at thirteen minutes and twelve seconds and the biggest one at twenty-two hours.

Another problem with the inventory range is the size of some SLCs. Some got so many materials in that just two of them are provided at a production line. If the supply trailer route system driver do not drive in a pre-defined cycle time, than the production line could run out of material. In case of MAHLE Filtersysteme Austria the drivers do not fulfil the given cycle times of thirty minutes, they are much faster. That does not lead to a big problem but will be evaluated in chapter 5.2 and chapter 6.2 in case of capacity and efficiency.

Inventory ranges have a kind of risk as well, because inventory ranges are not only valid for the production lines, they are also valid for the supermarket and the material warehouse. Those two the inventory ranges need to be coordinated by the customer’s needs and a loss risk calculation. In this thesis only the supermarket inventory ranges is going to be evaluated. (Gudehus, 2010)

Figure 4-12: Order paper for the supply drivers

Figure 4-12 is showing an order card of a production line where the inventory range in SLCs is visible. On the right side of Figure 4-12 the installation of these cards at a line can be seen. Above the card one provision point in the supermarket can be seen. The bar code on the bottom of the card needs to be scanned by the supply trailer route driver. On the top of the card there is the material description and below the material number of the part or material.

5 Development of actions

This chapter is dealing with the analysis of the processes and the weaknesses of them as well as optimizations.

5.1 Process-Analysis

The process analysis is following the guidelines of SIX-SIGMA and its DMAIC-cycle. Therefore, it is needed to define one starting process for the supply- and one for the disposal trailer system drivers first. The measurement of most process steps is done in chapter 4.4. This chapter is going to create the processes. The weaknesses of the created processes are going to be evaluated more in detail in chapter 5.2 by using a weakness analysis. (Waurick, 2014), (Günthner, et al., 2013)
The two processes of the trailer route system workflow are created in a way that after the weakness analysis a process optimization and a parallelization of some processes can be done and evaluated. Furthermore, team leaders and many employees support the creation of the processes. Real process creation and its drawing can not only be done by a single person. To create a real process many involved people are needed involved. (Günthner, et al., 2013)
The benefit of including all involved employees is that a process do not start on the paper first, it starts in a communication and an exchange of information with many parties. Another very important point is to listen to the employees and their suggestions for improvements and optimizations first. Afterwards a process close to reality can be created and drawn. (Günthner, et al., 2013)

5.1.1 Creating the two processes

The processes are created with consideration to BPMN processes. BPMN processes are setting the standards to draw graphically a workflow. Therefore, symbols are used to guide the reader through the process. In a BPMN activities, results and logical connections are drawn with pre-defined symbols. The arrows between the fields are leading the reader through the process and are explaining the flow of information. (Kossak, 2014), (Stiehl, 2014)
At the top of the process there is the starting event, in case of the trailer route system drivers for disposal the starting event was uploading empty finished goods trolleys on their trailer route system. The rectangles are the processes. Those process are mostly equal to the in chapter 4.4 measured sub-processes. The rhombuses are decisions the driver had to make during their rides.

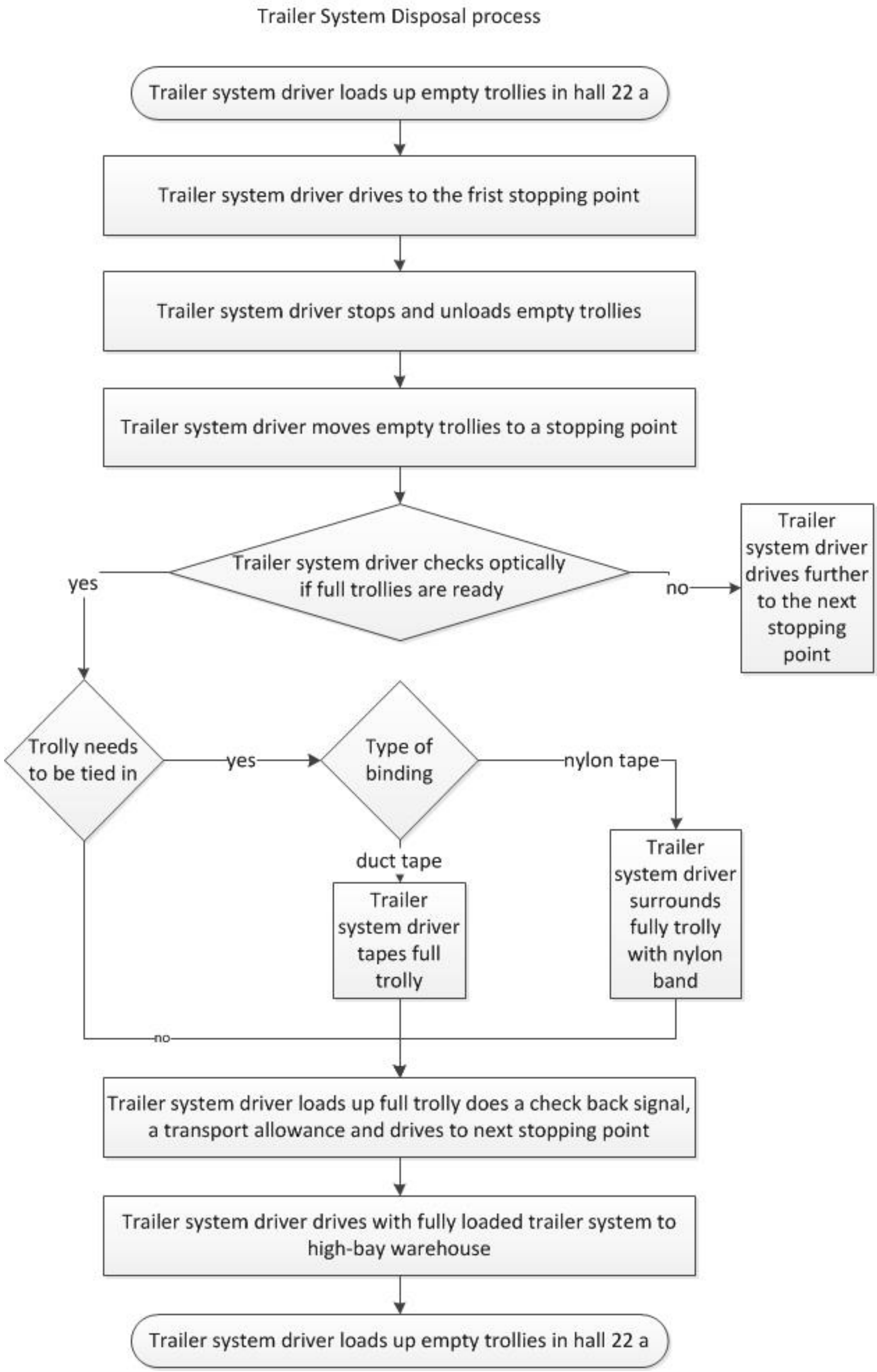

Figure 5-1: Disposal process

The supply process is starting with a lap the trailer route system driver does on a pre-defined route. During this lap, the driver is collecting the empty SLCs of the production lines and ordering new full SLCs for the next lap.

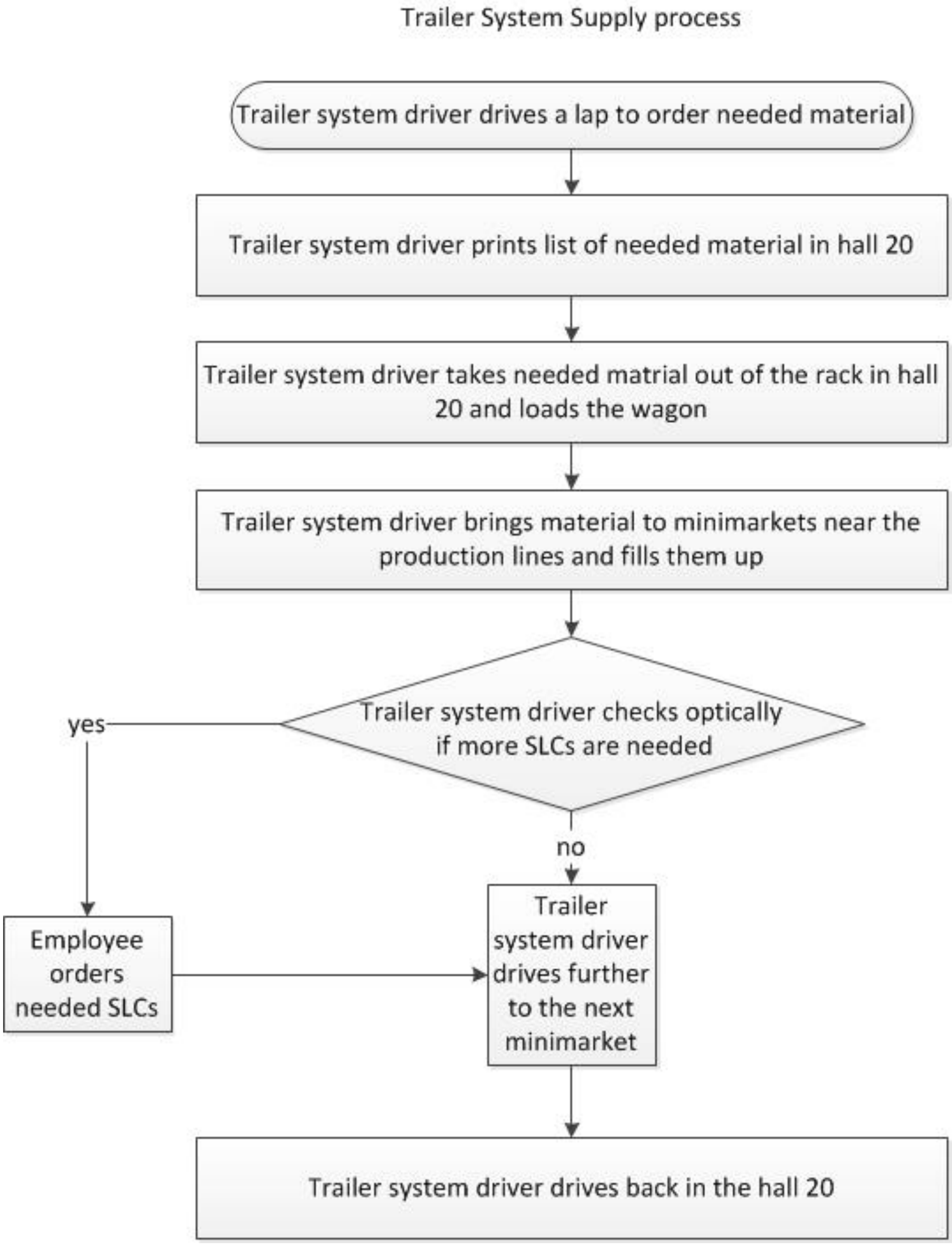

Figure 5-2: Supply process

5.2 Weakness-Analysis

Weakness analyses are systematically pointing out parts and steps of processes and sub-processes that include waste. Therefore, the analysis needs to be divided further into four major parts: (Günthner, et al., 2013), (Peschges, 2015)

- Technical weaknesses
- Organizational weaknesses
- Human weaknesses
- Strategic weaknesses

Benefit of this division is that the sources of these weaknesses in processes and sub-process can be highlighted and classified in groups. Through that classification a correct solution can be found much easier. (Günthner, et al., 2013)
Technical weaknesses for example can be a broken wheel of a trailer route system, or a not working SLC refilling channel. A maintenance team can eliminate these weaknesses.
The organizational weaknesses need to be divided further into inter-divisionally weaknesses and intra-departmentally weaknesses. To solve intra-departmental weaknesses meetings of employees and the head of the department solve the problem. To solve inter-divisional weaknesses the problems need to be highlighted first and then discussed with the heads of the involved departments. (Lunau, 2014)
Human weaknesses are caused by humans and can be eliminated for example by training them or standardize the working steps.
Strategic weaknesses are not going to be evaluated in this thesis.
To do weakness analysis it is needed to create a list of weaknesses than prioritize them. Afterwards the most important weaknesses need to be analysed. Solutions and improvements for the weaknesses are needed to be found. At last the solutions and improvements need to be implemented in the system. (Lunau, 2014)

The following table is showing the classification of the weaknesses evaluated at MAHLE Filtersysteme Austria and a short description of the solutions:

Table 5-1: General weaknesses

Weakness description	Technical weakness	Organisational weakness	Human weakness	Solution
No predefined stopping stations		X		Add predefined stopping stations on the ground
High traffic volume		X		Combination of two routes and increase cycle times
Information-flow	X	X		Information exchange written not verbal
Shift handover		X	X	No pre-buffering
Warehouse arrangement	X	X		Introduce order picker

Table 5-1: General weaknessesTable 5-1 is showing the weaknesses and their classifications for all trailer route systems of segment 15. Chapter 6 is dealing with solutions worked out in the weakness analysis.

The first point of this analysis is the high traffic volume. That is a problem for the trailer route system drivers as well as for the safety. To decrease the traffic volume it is needed to convert the supply for production line eleven from forklifts to trailer route. That point is furthermore introducing the next point of jams caused by no predefined stopping stations on the roadways. The is-measurement shows that for the supply and disposal system nearly one hour of waiting time is excepted. That is considering in the LEAN methods as pure waste. So it is needed to introduce clearly pre-defined stopping stations on the ground for the drivers to stop the system and supply the lines.

The next two points go together in the weakness analysis. One is the information flow and the other the shift handover. The information flow is often not working well. For example employees of the production lines are told to inform the trailer system drivers about of new line set ups or still standings early enough. In many cases that is not working. Chapter 6.4 is dealing with an improved information system.

The last point in the general analysis is the warehouse arrangement. During the is-analysis it turned out that the warehouse must be reorganized. The current set up of the warehouse causes traffic jams and blockades as well as creating safety hazards. Chapter 6.6 is dealing with the problems and weaknesses of the warehouse called supermarket hall twenty.

Table 5-2: Weaknesses of the supply system

Weakness description	Technical weakness	Organisational weakness	Human weakness	Solution
Information-flow line to driver to material preparer		X		Install a written or clear visible system
Material supply	X	X		Create a list for high runner materials
Pre-buffering			X	Block buffering constructional
Confusion of materials	X		X	Poka Yoke
Jams in the supermarket	X	X		Introduce order picker
Narrow & slippery roads		X		Consider trailer route system in planning
No predefined stopping stations		X		Add stopping stations on ground
Searching the scanner		X		Buy support belts
Long walking ways trolley to line			X	Take trolley of the trailer system
Heat exchanger wagon	X	X		Install a conveyor belt
No predefined order limit	X	X		Create a limit for huge orders in SAP
Printer position		X		Position it on a new place
Warehouse layout	X	X		Rethink the layout
Standardization		X		Introduce new standards in all segments

Table 5-2 is showing the main weaknesses of the supply trailer route system, which are going to be improved in this thesis.
The first point is mentioned in the general weakness analysis but is also very relevant for the supply drivers. Most of the time the drivers do not get any

information about new line set ups. This results in wrong deliveries and sometimes in production line downtimes.
The second and third points are referring to the provision of material in hall 20. In some cases during the is-measurement the needed material is not provided in the supermarket on time. Sometimes this leads to supply production lines not in time. The experienced trailer system drivers buffer those materials on their trolleys to give the warehouse employees enough time to refill the supermarket channel. Material buffering by experienced drivers is not preferred solution for that weakness. To optimize this procedure a solution is shown in chapter 7.1.
Mixing up different materials happened twice during the is-measurement. Mixing up of material is a very big point in automotive industry. Not identifying wrong material can lead to line shut downs. This point is going to be elaborated more in detail in chapter 6.9.
The current layout of the supermarket is causing some jams close the loading and collections zones of the SLCs. The layout of the supermarket is done in chapter 6.6.
Repeated looking for the ordering scanner is waste of time during the is-measurement. The solution to eliminate this problem is to carry the in scanner on a hip belt. Those belts are buckled up on the hip, so the scanner is always with the driver.
The next point is related to the education of employees and their health. Most supply drivers leave the trolley on the e-typed frame and carry every single SLC to the line. This is in consideration to LEAN management pure waste. The better solution is going to be to take off the e-typed frame and push it to the line. This is going to reduce the handling time at a line of more than 50 percentages and reduces the carrying ways for each single SLC.
The next weakness identified is the loading of the heat exchanger wagon for production hall 20. The driver has to pick up the heat exchangers piece per piece and load it into the wagon. Loading and unloading takes six minutes during each lap. This weakness is elaborated more in detail in chapter 6.1.2.
One of the last points identified is the not defined maximum order limit of material. The trailer route drivers tend to order as much material as available in the supermarket in order to decrease the movement in the supermarket as much as possible. On the hand side it is a benefit for the movements in the supermarket on the other hand it reduces the free capacity of the supply trolleys.
Printer position, warehouse layout and standardization are three of the main points of concern turned out during the weakness analysis. They are elaborated more in detail in chapter 6.3, 6.6 and 6.10.

Table 5-3: Weaknesses of the disposal system

Weakness description	**Technical weakness**	**Organisational weakness**	**Human weakness**	**Solution**
Information-flow: line to driver	X	X	X	Introduce Pizza-Service
Rails close driveway		X		Remove rails of the driveway
Jams in H22a	X	X		Introduce Pizza-Service
Long drive times from H22a to lines		X		Build a new supply hall
Binding of finished trolleys	X	X		Create a paper with binding rules
Reply time	X			Emit reply time from driver to production
Needed finished trolleys		X		Introduce Pizza-Service
provisional packing for finished goods		X		Better supply of customers

Table 5-3 is showing the summary of the weakness analysis of the disposal system. Information flow turned out as one of main weaknesses of the disposal system and will be explained in more detail chapter 6.4.
The steel barrier protecting the walkway in hall 21 and 22 is also one weak point of the system. This barrier is limiting the operating space for trailer systems and forklifts causing traffic jams to occur. New production lines installed also reduce the operating space for trailer system. This is one reason why a trailer system and a forklift barely have space to pass. Solution for this problem is to disassemble the boundary barriers of the walkway and install information shields of the danger.
Long travel ways between the provision of the empty boxes in hall 22a and the production lines is structurally given, caused by the historical growth of the company.
Traffic jams in hall 22a, the need of empty finished good trolleys and provisional packing for finished goods are going to be elaborated in chapter 6.4.

6 Methodology of the approach

This chapter is dealing with different approaches for optimization of the trailer route systems. Therefore, the supply trailer route systems is divided in single supply routes. For the disposal system a conceptual solution is developed.
In the following sections layouts, picture and key performance indicators are showing the benefits of the different approaches.

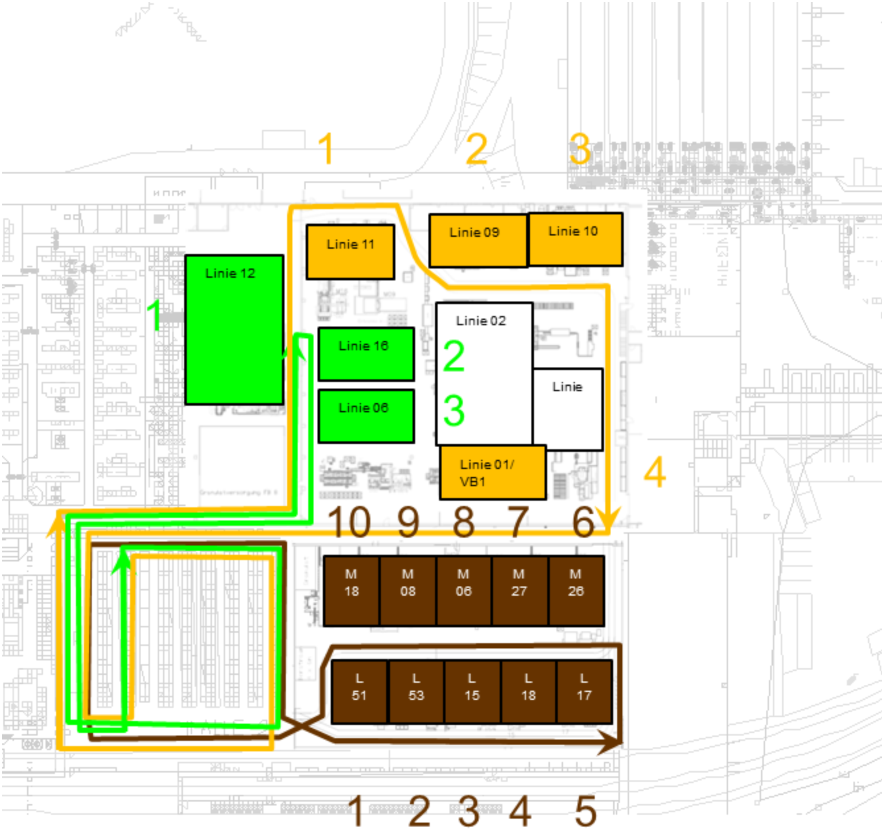

Figure 6-1: Detailed view on supply routes for segment 15

6.1 Optimizing supply train 1 for production hall 20

The supply train of production hall twenty sets the capacity limit during the is-measurement. The system transported 151685 SLCs during the evaluation period starting in January 2015 and ending in August 2015. The drivers of that supply trailer route system are busy during the whole shift. One point for the high workload of the driver is the loading and unloading of the heat exchanger wagon to supply production lines with heat exchanger wagons. In addition the high workload is caused due to the fact that production hall 20 has several high runner lines. High runner lines for production hall 20 are defined as production lines running on a capacity of more than 1000 parts per shift and continuous material supply. Another point of concern is that some material filling stations are far away from possible stopping areas for the trailer route system. This is causing long walkways for the driver in order to supply the SLCs. The is-measurement is transporting an average number of 10,3 SLCs per lap.

6.1.1 Variant 1: shorten the route

The trailer route system for production hall twenty needs to drive through the whole warehouse, which has been identified as waste. The material is already placed on the right hand side of the supermarket, while the empty collection points are spread left hand area of the supermarket. (see Figure 6-2). This is causing unnecessary driving distances just in order to return empty SLCs and printing the picking list for the ordered material. This time for driving the system through hall 20 can be used as value adding time for handling on the lines or ordering needed SLCs.
Shortening the route by optimizing the supermarket as described in chapter 6.6 leads to a time saving of 28,5 seconds each lap.

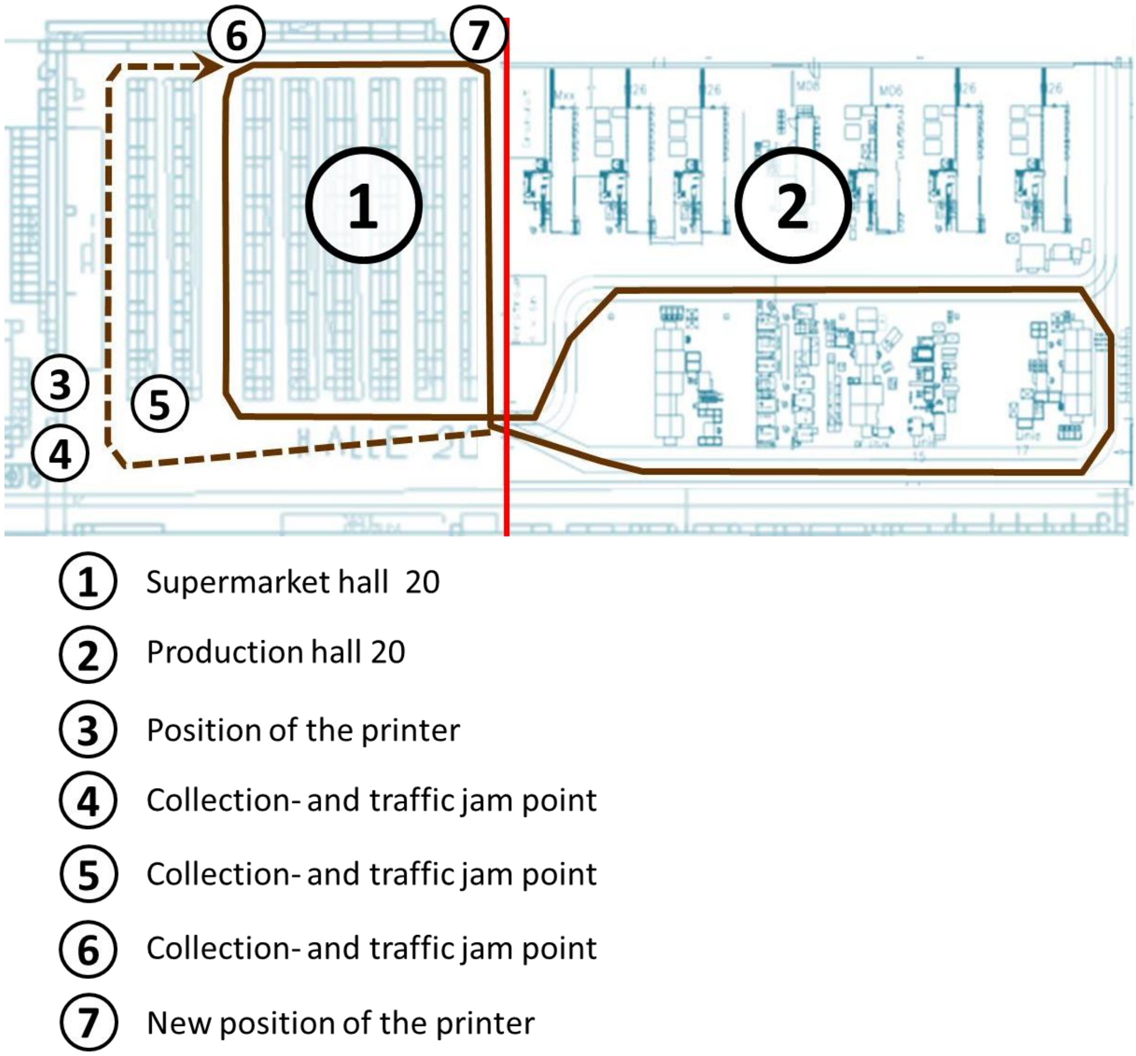

Figure 6-2: Route optimization in the supermarket

Figure 6-2 is showing the route of the trailer system for production hall 20 and the supermarket. The dotted line shows the travel line during the is-measurement, the full line shows the optimized route in the supermarket in hall 20.

6.1.2 Variant 2: elimination of the heat exchanger wagon

This variant is dealing with the elimination of the heat exchanger wagons for production hall 20. The is-measurement shows nine to ten times the heat exchanger wagon must be loaded during one shift. A planned increase of production for 2016 will lead up to a maximum of 14 times of loading these heat exchanger wagons per shift. Calculations based on the time taken during the is-measurements for loading the heat exchanger wagons, this will lead to 84 minutes of handling trays with heat exchangers per shift in 2016. This is identified as pure waste, due of the movements and the stacking of the trays in the wagon. Furthermore the height the trays must be lifted manually is a point of concern for the drivers and employees of the line. Figure 6-3 is showing the heat exchanger wagon and the needed movement to fill it.

Figure 6-3: Heat exchanger wagon for production hall twenty

The optimization of this process results in a conveyor belt suppling the heat exchangers. This new process is going to be 61,1 percentages faster than the old process because the driver is going to need just two minutes and 20 seconds for the whole supply process. Main reason for the improvement of this process is the bigger batch size of six trays instead of two the driver can handle.

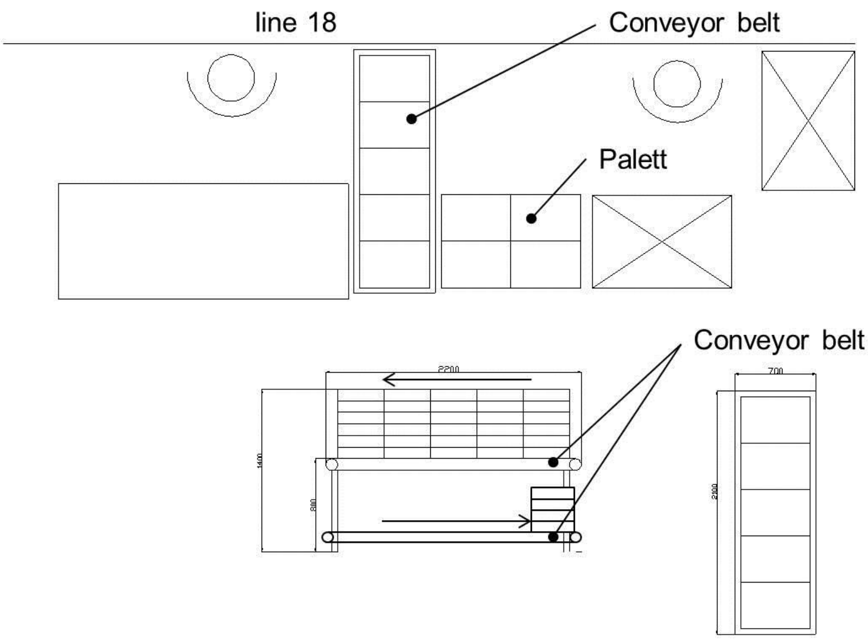

Figure 6-4: Conveyor belt for line seventeen and eighteen

Figure 6-4 is showing the concept solution of the supply for line 17 and 18 with a conveyor belt. One positive effect is the supply and disposal by pallet and special trolley for the lines. The other point is the ergonomic height for the supply drivers, line employees and the no longer needed removal of the trays by the line employees. The belt is protecting the drivers and employees of back injuries and the supply of materials is faster.
One pallet of the heat exchangers has a capacity of at least 48 trays and in best case 60 trays. The transport of the pallet trolleys is possible with the trailer route system. To optimize the disposal of the empty trays a special trolley has been developed and tested during the study for this thesis. Figure 6-5 is showing the new disposal trolley for production hall 20.

Figure 6-5: New developed removal trolley for supply system

The driver is stacking the batches of trays on the new trolley and then moves the trolley to the trailer system. That new process step is going to reduce the walking distance of the driver by the factor of four. Parts of this process have been tested during this thesis. Due to the high costs of a belt conveyor this still remains a concept solution. Instead of the belt conveyor a roller bed has been build to supply the production lines with heat exchangers.

Figure 6-6: New supply conveyor for production line seventeen and eighteen

This new process is faster as the old one but needs more space on the production ground than the heat exchanger wagon and the suggested conveyor belt solution. This new roller bed allows only a batch size height of three tray instead of six trays for the conveyor belt concept. This fact leads to a bigger footprint of the roller bed compared with the conveyor belt and heat exchanger wagon. Therefore it can not be installed on every individual line. One reason for speeding up the process is the supply by pallets and the increased batch size height of three trays compared to two trays of the wagon. One target of this thesis is to provide as much material as possible on little spaces. The conceptual solution of the conveyor belt enables material provision of six trays above each other, faster supply and the ergonomic factors.

6.1.3 Variant 3: increase the cycle time

The third variant for the supply trailer route system of production hall 20 is dealing with increasing the cycle time of the supply rides. During the is-measurement the system has an average cycle time of 24 minutes and 56 seconds. The longest time of one lap is 39 minutes and 22 seconds. The heat exchanger wagon, the roller bed or the concept of the conveyor belt is setting the longest cycle time for production hall 20. An increased cycle time is going to lead to less drive time and more value adding handling time at the lines. Furthermore the capacity is better utilized because more material is transported on the system each ride. The optimized cycle time is related to the consumption of heat exchangers set by the two high runner lines. 2016 line 17 is going to produce 168 oil filter modules every hour, which needs the same amount of heat exchangers. That huge amount of finished products is going to need a well working material supply and provision.
The cycle time of the trailer route system can be raised up to a 72 minutes per lap including a short buffer of one minute at the high runner lines 17 and 18.

This cycle time is calculated for the future planned supply per line with conveyor belts or roller beds. To fulfil this cycle time the supply of material in the supermarket needs to be provided without waiting times for material supply drivers.

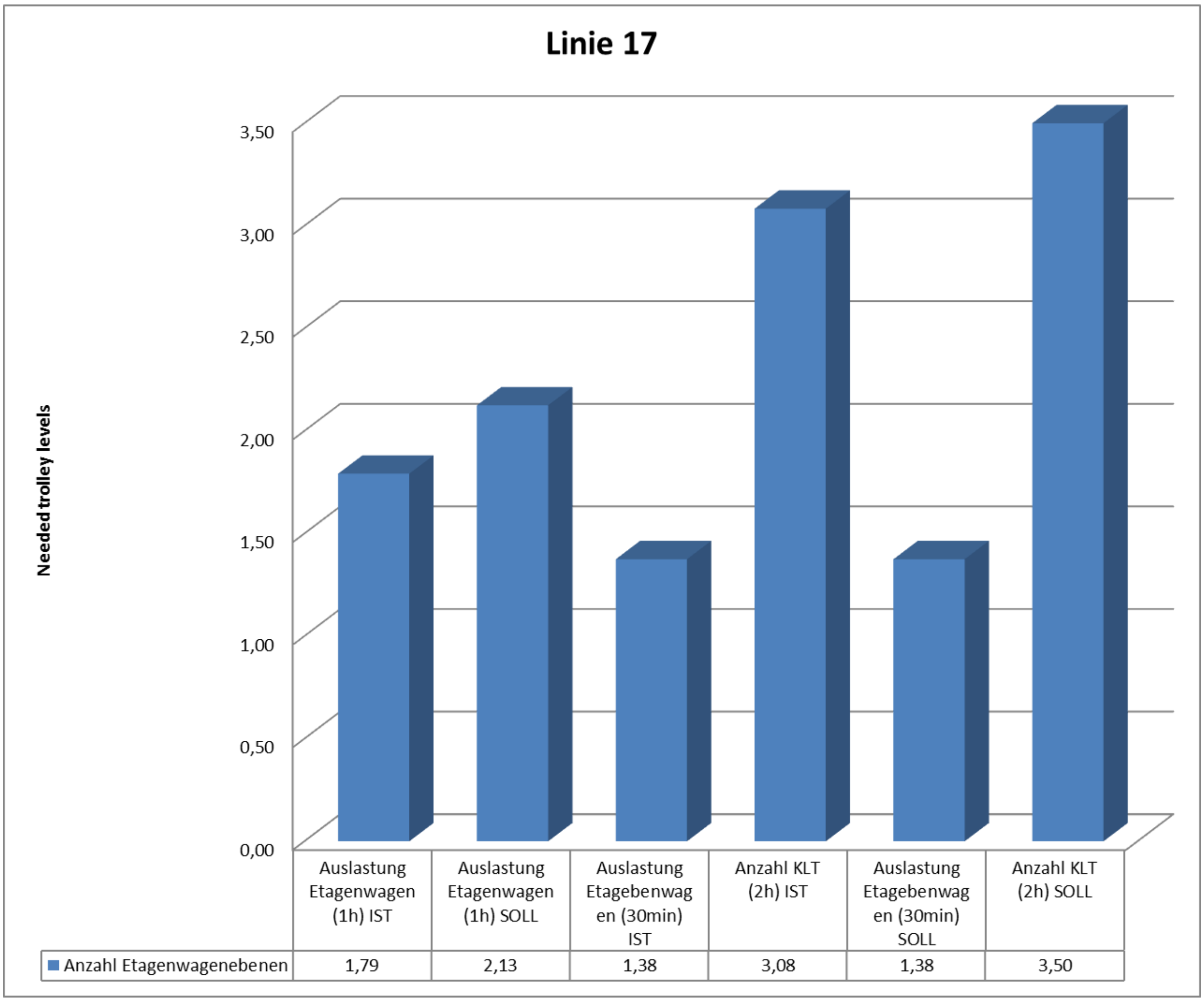

Figure 6-7: Exemplary plot of the needed SLCs per lap for one production line

Figure 6-7 is showing one plot to compare the SLCs needed to deliver for a single ride of the supply trailer route system, which is going to be explained more in detail in chapter 6.5.

6.2 Optimizing supply trains 2 and 3 for halls 24 and 25

During the is-analysis and is-measurement of this thesis it turned out, that if production line twelve is not running and the trailer route system is faster as the predetermined cycle time unloaded drives on the short supply route occurred. One main point of this chapter is to work out how a combination of these two routes can be done.
The fourth variant of this chapter is going to describe a tested conceptual solution. This solution is going to provide a reduction of space needed to supply material and relates strongly to the ergonomic of the driver.

6.2.1 Variant 1: changeover of one production line to full trailer system supply

Production line eleven in segment 15 is not fully supplied by trailer route systems during the is-measurement and its analysis. Only 50 percentages of the supply are done by trailer system. That line has an employee belonging to the warehouse staff in each shift who orders material needed for that line. Forklifts delivered the material to predefined transfer points. Employees pick up the material and bring manually or by hand pallet trucks. The workday for these employees is quite boring, because depending on the amount of produced oil filter modules the employees are waiting up to 45 percentages of one shift.
The trailer route system of the long yellow coloured route in Figure 4-6 is already suppling some parts to the production line eleven and is not running on full capacity. It has been decided to change the supply of the line eleven to total trailer system supply. This caused that the employee transporting the material manually can now be used on a new installed working place called the order picker. This working place is going to be explained more in detail in chapter 6.3. Another positive effect of the supply changeover of that line is an increase of safety, because no forklifts are driving close to the footpath of 100 meters anymore.

Figure 6-8: The way of forklifts close to the footpath to line elven

6.2.2 Variant 2: increase the cycle time

The group leader of internal transports predefined a cycle time of 30 minutes. All supply drivers are instructed to do cycle times of 30 minutes. During the is-measurement and the analysis it turned out that the average lap time of the short, green coloured route in hall 24/25 is 18 minutes and 22 seconds. The long, yellow coloured route has an average lap time of 21 minutes and 49 seconds. These two average times are far away of the predefined 30 minutes for one cycle. With these average cycle times each supply system does between 21 and 25 rides per shift.
The inventory ranges of the two supply routes are between 49 minutes at line nine and 137 hours and 30 minutes at line one. The majority of the inventory ranges at the lines are lasting for more than two hours. This leads to a rethinking of the layout of the supply system in terms of route and cycle times. Increasing the cycle time is going to lead to a better utilization of the trailer system capacity. The unloaded rides on the short supply route will be eliminated as well. Furthermore the value adding time of the driver for handling at the line is going to be increased, because the ride time is going to be decreased through that variant.
The new developed cycle time is 57 minutes and 45 seconds. This time is calculated by maximum the amount of 16 trolleys carrying a pallet full of SLCs out of the supermarket into the production hall 24/25. This number is the maximum amount of trolleys needed to supply the combination of the two supply routes. In case of MAHLE Filtersysteme 94,2 percentages of the already existing inventory ranges at the minimarkets of production hall 24/25 are already able to fulfil a cycle time of nearly one hour. Only seven minimarkets need to be adjusted to a cycle time of one hour.

6.2.3 Variant 3: combination of the supply routes 2 and 3

This variant is combining the two supply routes of segment 15. Therefore it is needed to adjust the number of minimarkets of chapter 6.2.2.
The time analysis of chapter 4.5 shows that a combination of the two supply routes is going to lead to a theoretical maximum cycle time of 58 minutes and 26 seconds. This time is 41 seconds longer as the in chapter 6.2.2 calculated new cycle time. That is one reason why during this thesis an order picker is introduced. Chapter 6.3 is dealing with the order picker. Subtracting the picking time of the combined total cycle time the theoretic time is 45 minutes and 46 seconds. This time is far below the new calculated cycle time of chapter 6.2.2, which is 57 minutes and 45 seconds. Theoretical a combination of the routes is feasible. In chapter 7.2 the combination of the routes is tested and evaluated.
A combination of the yellow and green supply routes is going to lead to massive decrease of traffic on the roadways because the supply is going to be done by only one trailer system. That is going to lead to an increasing safety of the segment. Furthermore the traffic jams caused by a high traffic of trailer route systems on the roadways are also going to be nearly eliminated by that action.
During this thesis only two minimarkets have been adjusted to this idea. Five of them have been on the old inventory ranges, which is a bit too low to guarantee a well working combination of the two routes. Mistakes occurring during the supply or provision of material caused the implementation to be postponed.

In case of the production line nine the actual minimarket is nearly too small for a thirty minutes cycle time. So it is needed to think about a new solution how to bring more SLCs with heat exchangers to a line without using more space as available. If the combination of the two routes is going to be implemented to the supply trailer route system a driver is going to lift around 7000 kilograms every shift. This is the weight of the heat exchangers needed to be lifted if all production lines are running. That is another point for a rethinking of the existing system with the supply roller conveyors.

6.2.4 Variant 4: working with towers

Variant four is describing a solution, which is strongly referring to space and ergonomic. The way how the production lines are supplied with material during the is-analysis is to lift SLCs or trays with heat exchangers on a roller conveyor. On this roller conveyor there is the possibility to load SLCs or trays just single or in some cases double above each other. The space such roller conveyors needed in the production halls is sometimes massive. If the system is running on two separated routes the driver of the short route needs to lift 4045,6 kilograms and the driver of the long route around 2986,4 kilograms.
A solution with positive effects on the drivers needs to be found to relive the huge workloads. Working with towers was developed. Figure 6-9 is showing a full loaded trolley of SLCs typed 6280. Most of the heat exchangers are stored in such SLCs.

Figure 6-9: Full pallet with SLCs and a SLC tower

For working with towers it is needed to bring one trolley of heat exchangers to the new roller conveyor. Afterwards pull the tower off three SLCs of the pallet and on the new roller conveyor over a connection of the conveyor and the pallet. The tower of three SLCs than rolls on the conveyor to the production line and stopped first by three separation points. (Arnold, et al., 2008)

That solution is going to reduce the costs per square meter in the production halls for providing material with a factor of three. Furthermore it is going to improve the working conditions of the supply trailer route system drivers.
Has the tower of SLCs passed the last separation point it stops on a lifting system close to the line. That lifting system is going to lift the SLC tower in the ergonomically best height for the line employees. The line employee just needs to pick out the needed heat exchangers of the SLC. If the SLC is empty, the next SLC of the tower is lifted up to the same height as the previous SLC was. When there is no SLC left on the lifting system, the platform of the lifting system goes down and the next tower comes on the platform and the procedure starts again.
Figure 6-10 is showing a schematic sketch of the involved area of production line nine, the new roller conveyor, the pallet with the towers of SLCs, the lifting system close to the line and a side view of the gravity principle.

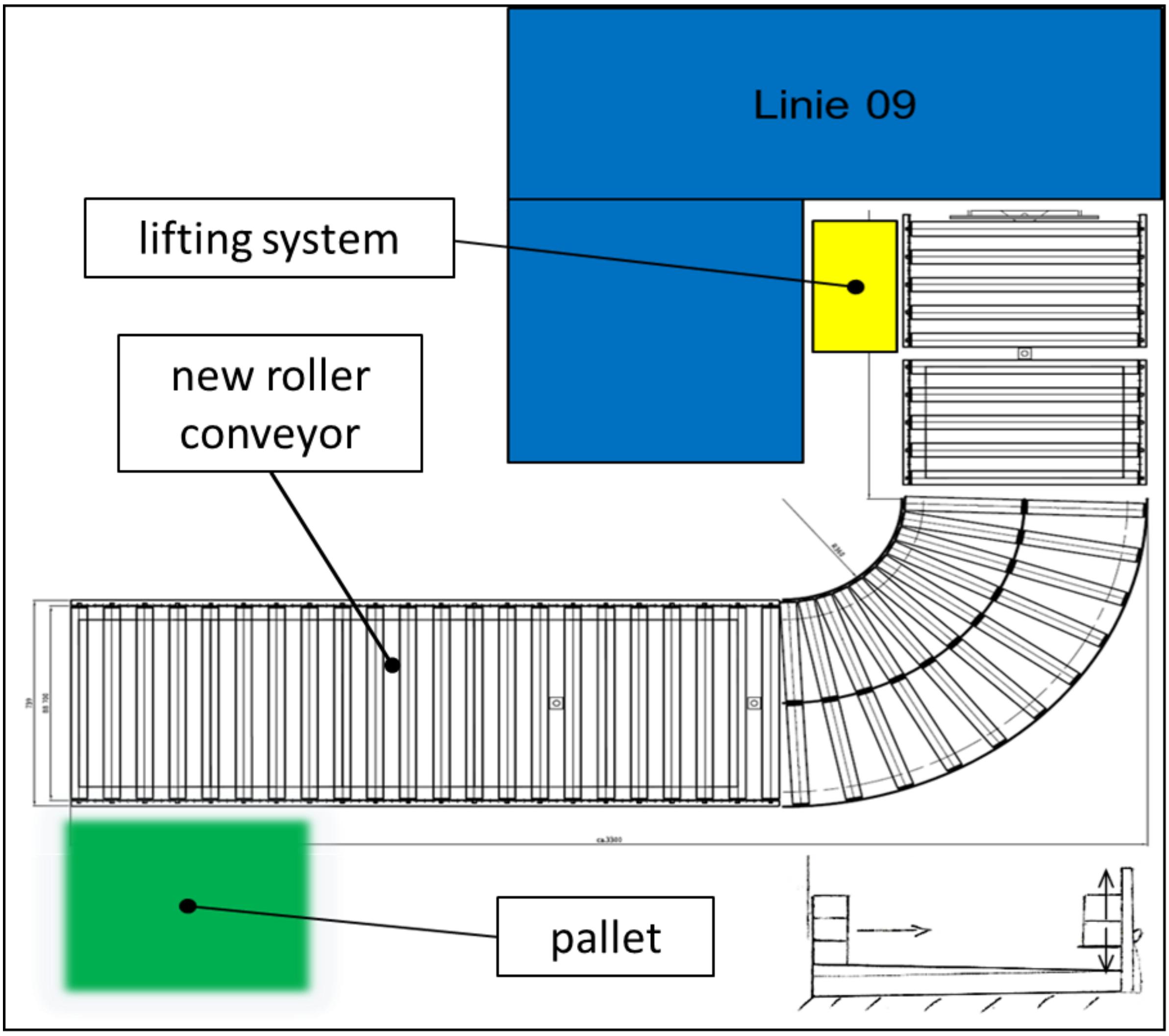

Figure 6-10: Solution of working with towers for line nine

6.3 Creating a new working place the order picker

In the old process every supply trailer route system driver works on his/her own supply process. In the weakness analysis it turned out that there are traffic jams and blockades at some places in the supermarket in hall 20. To eliminate that traffic jams and blockades it is needed to restructure the supermarket explained in detail in chapter 6.6. Furthermore, it turns out that the picking time for all three supply trailer route drivers together is in average five hours and 24 minutes during the shift. The order picker is introduced to fulfil the most difficult operation in the supply process, the picking. (Gudehus, 2010)
The free employee of line eleven, as explained in chapter 6.2.1 is trained to fulfil the tasks of the order picker. Another important point is that through the introduction of an order picker some process steps of Figure 5-2 are going to be parallelized. The parallelisation of process steps includes for the case of supply drivers more time for value added processes like handling at line because the picking time is moved to the order picker. (Klug, 2010)Figure 5-2
The tasks of the order picker are: (Gudehus, 2010)

- Supply materials in SLCs or trays
- Moving to the points where material is stored
- Take required amount of material
- Put SLCs or trays onto trolleys
- Organize the order of material on the trolley

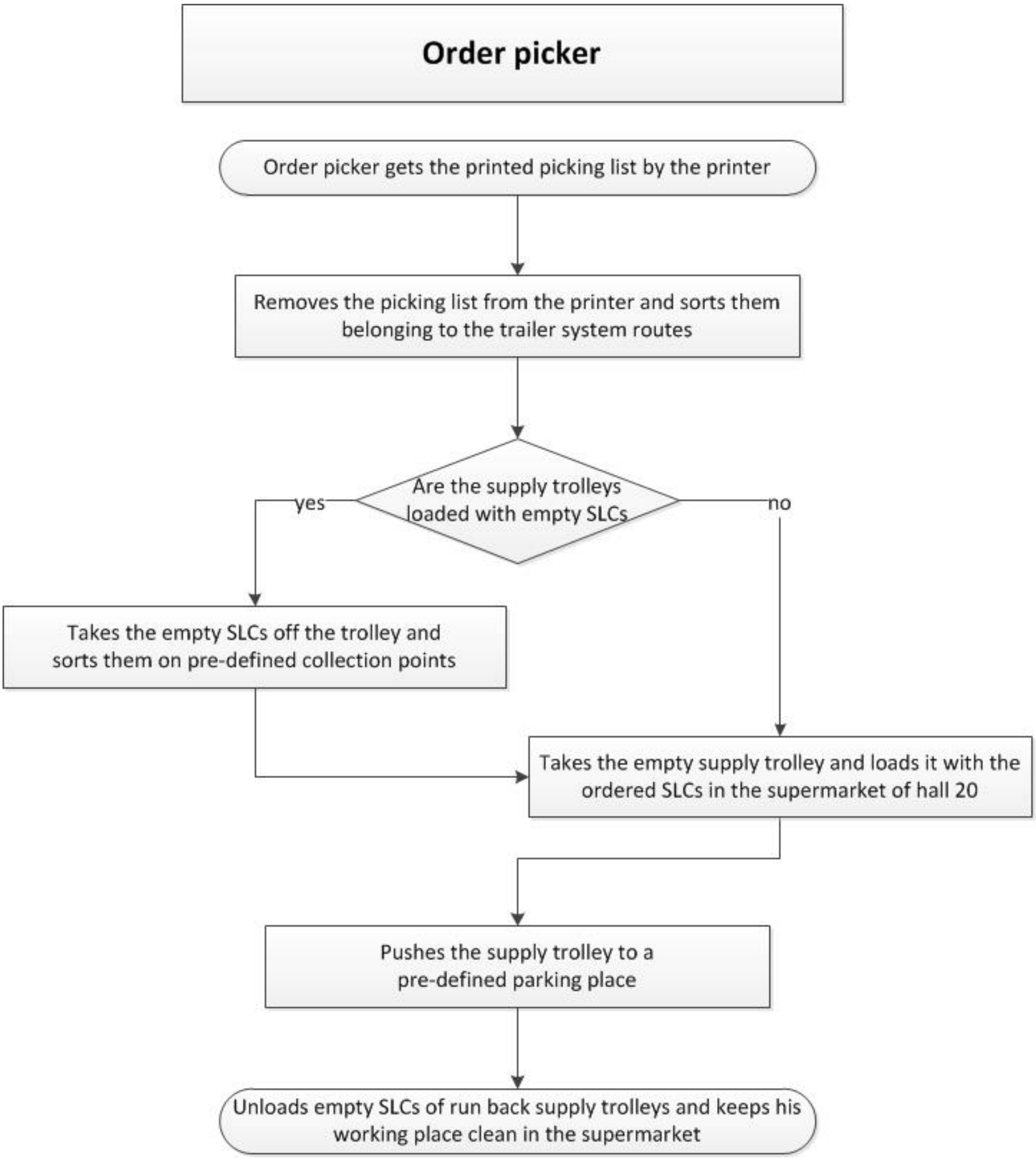

Figure 6-11: New process of the order picker

Figure 6-11 is showing the process steps for the order picker. At the system currently running at MAHLE Filtersysteme in segment 15 the order picker gets a printed picking list provide by the supply system drivers. Based on this picking list the order picker provides the ordered material on trolleys. To print such lists it was needed to adapt the SAP functions of the old ordering process to the new process. (Klug, 2010)

At the old system, after the supply driver has passed the last supply line with the order scanner the list was send to the printer. This system do not allow enough time to process the picking list. Therefore it is needed to split up the order into suborders for every single production line. Through the ordering per line the order picker gets every order for each line on a separate list, which lead to a line organized picking on the supply trolleys. Another improvement is that the picker dropped the order list for each line close to the ordered SLCs so the driver does not need to search for each SLC at a line. (Klug, 2010), (Göpfert, et al., 2012)

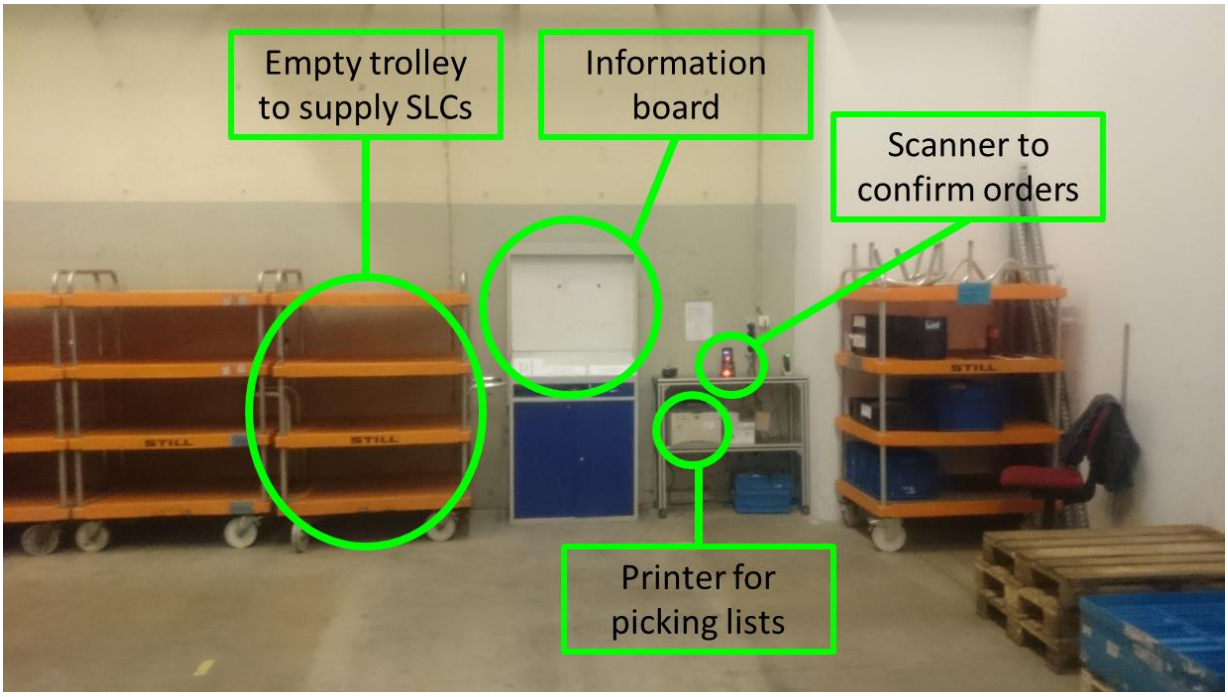

Figure 6-12: New working place of the order picker

Figure 6-12 is showing the new work place of the order picker in the supermarket in hall 20. On the left side of the picture empty supply trolleys for SLCs and trays are standing. In the middle there is an information board for the trailer route system drivers and the order picker. On the table on the right side of the picture a printer is installed. Furthermore the picker got a scanner to confirm the ordered materials afterwards he/she picked them and dropped on a trolley.

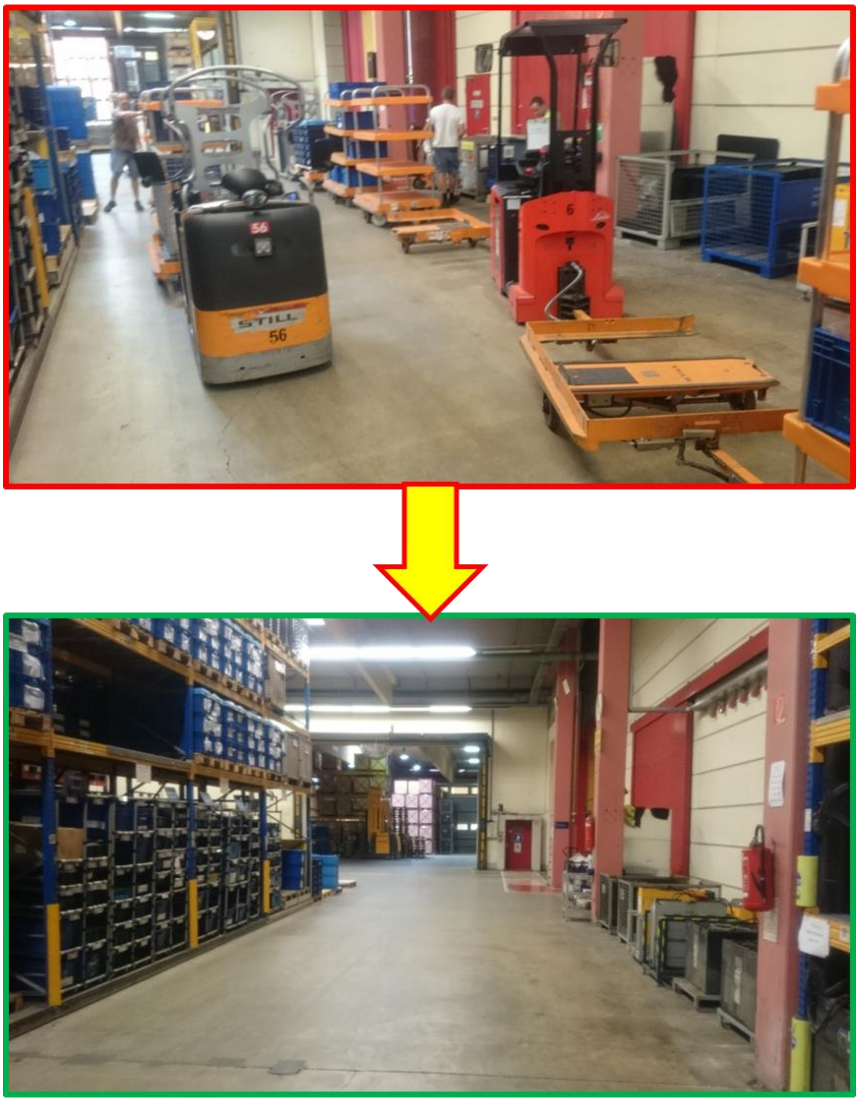

Figure 6-13: Visual comparison of before and after the optimization

Figure 6-13 clearly shows the positive effect of the order picker at one of the previous traffic jam locations. At the shown location in Figure 6-13 normally trailer route systems, forklifts and employees need pass the corners. The introduction of the order picker also leads to increase of safety.

6.4 Optimizing information system for disposal trains

During the is-analysis and the weakness analysis it turned out that false deliveries of empty boxes for finished goods occurred in the disposal system. Mostly these false deliveries occurred because the team leaders of the production lines did not inform the disposal driver about a new line setup. Another reason was that the drivers forget the new set ups. Therefore it is needed to develop a new system to eliminate these wrong deliveries and create an improved system.

Actually there is no possibility to order empty finished good boxes by the SAP system of MAHLE Filtersysteme. Therefore it is needed to classify the different boxes and their inserts in the SAP system first. After some surveys it turned out that during this thesis 35 possibilities of different box and insert combinations are in circulation.

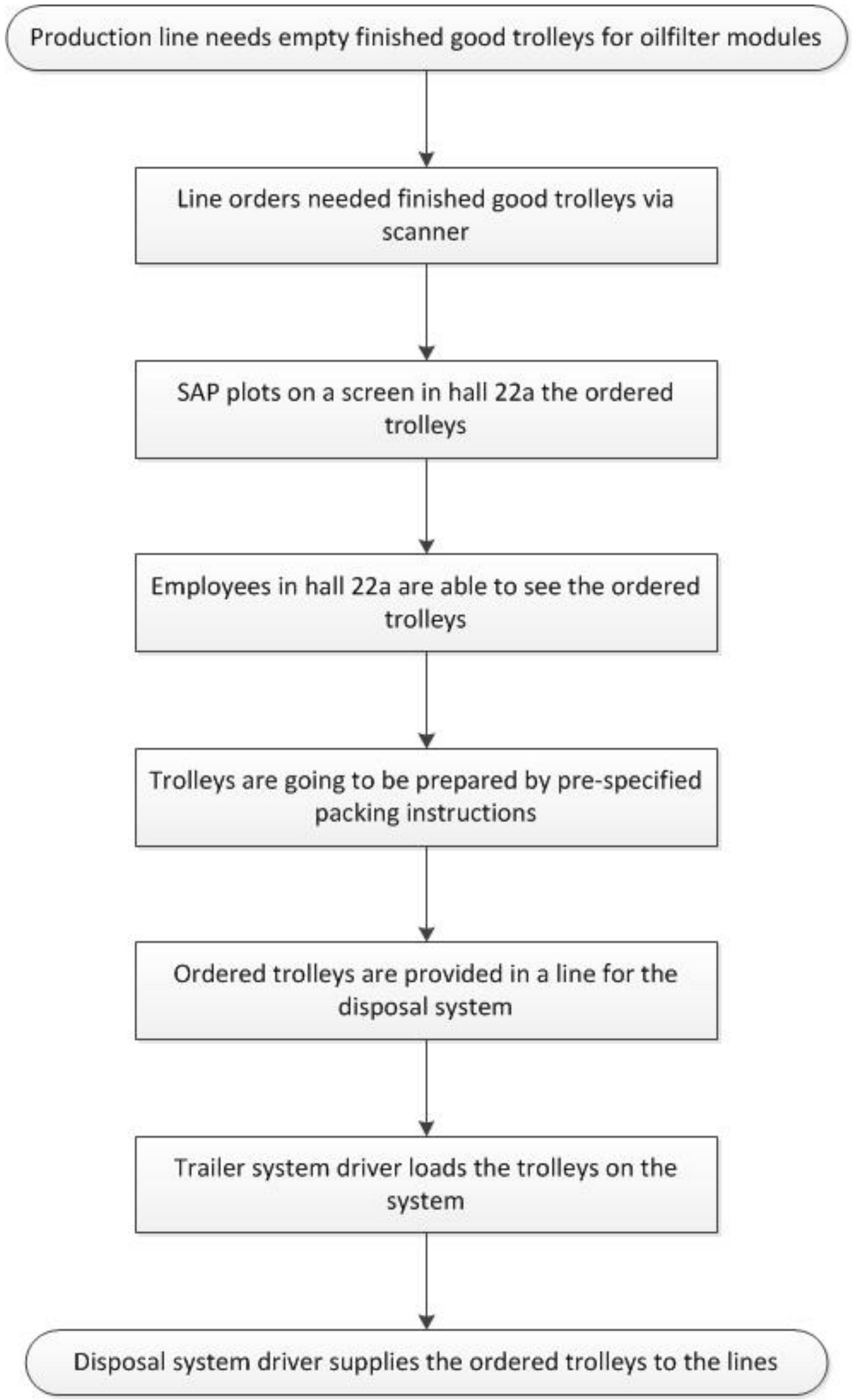

Figure 6-14: Concept process of the disposal system

Figure 6-14 is showing the concept process of the disposal system. In this process false deliveries can hardly occur. A positive aspect for the trailer route drivers is that the lines have to order the boxes and take the responsibility. The production lines are going to order the boxes and inserts with scanners similar to the supply trailer route drivers and their process for ordering material from the supermarket. The SAP system is providing the information about the ordered boxes and inserts in hall 22a. The ordered boxes are prepared according to pre-specified packing instructions in hall 22a. The boxes are provided in a line so the driver just needs to put them on the trailer system and deliver them to the lines.
This process also increases the flow of information, allowing the buffer zones to be reduced massively and reduces workload of the personal.

6.5 Development of an Excel-File for the needed SLCs with the needed inventory range

One main point of this thesis is to develop a possibility for a pre-calculation of the amount of needed SLCs per production line and to gain a feeling of how many levels the trolleys need to transport the SLCs. Another very important point is that the inventory ranges of chapter 4.6 are calculated by the production and not by the supply team. The file is also showing an overview of the given inventory ranges and an overview of the needed and possible ones for each production line.
For this calculation the program Excel of the company Microsoft is used. The calculation is following the guidelines given in literature by Arnold & Furmans and Günthner & Durchholz.
To calculate the amount of needed SLCs first it is needed to gain all relevant data for every single oil filter module. The first step is to gain the bill of materials for every module. On this bill of materials all components of an oil filter module are listed. Some of the components are produced on production lines of MAHLE Filtersysteme and not delivered through the supply system. Therefore interviews with employees were done to get knowledge which parts are supplied by trailer systems. (Arnold, et al., 2007), (Günthner, et al., 2013)
The next step is to create links in the file to up to date databases, where for example the quantities of every part per SLC was stored. Other links are used to get the type of SLC in the file.
Functions of the Excel-file:

- Calculation of needed SLCs per production line
- Quantity of parts per module
- Compares target state with current state
- If query, calculates number of needed levels of supply trolleys
- Bar chart plots the number of SLCs for different lap times
- Current, needed and maximum of the inventory range
- Needed SLCs for lap times

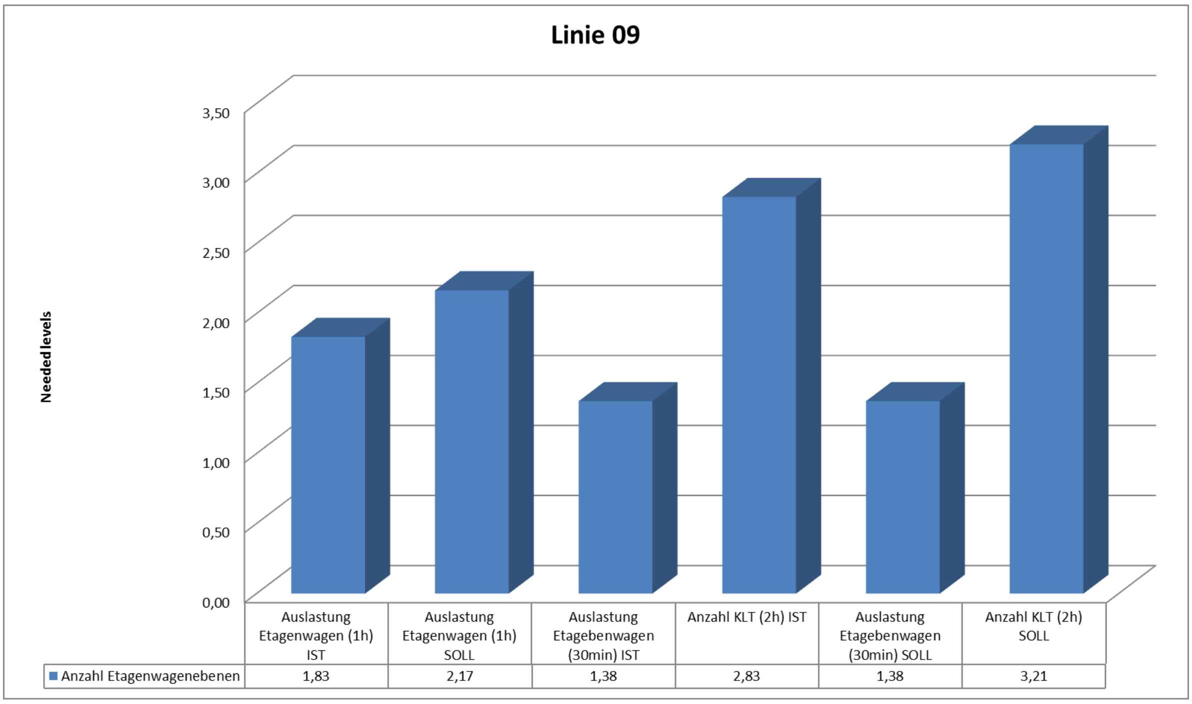

Figure 6-15: exemplary plot of the needed SLCs per lap

Figure 6-15 is showing an exemplary plot of the Excel-file, where the needed levels on a supply trolley can be compared to the lap times. The step between the cycle time of 30 minutes and one hour is much smaller than the step between one hour and two. That was another fact why a rethink of the supply routes is done. Another function of the file is used to calculate the number of levels a supply trolley needs to transport the needed SLCs. That calculation showed that the actual supply trolleys were too small to combine the supply route two and three if all production lines were running. To solve that problem two new supply trolleys are ordered and built.

6.6 Optimizing of the Supermarket in hall 20

Supermarkets in automotive companies are logistic systems close to production areas. Supermarkets are the main distribution points for supplied materials. The name came from American supermarkets, where everything is available and ready to be picked up. The first supermarket was introduced 1953 at Toyota. The provided material in automotive supermarket should be oriented on the number of produced goods for the production. (Klug, 2010)
The analysis has shown that a walking way optimization in the supermarket of MAHLE Filtersysteme needs to be done. Some high running materials need thirty steps to reach the storing place. For those thirty steps in one direction the order picker needed 24 seconds. These 24 seconds are pure waste in case of unnecessary ways and transport time. Other materials, which are used just sometimes, are located very close to the order picker place. Therefore a walking way optimization of nine materials is done. The high number of collection points for empty SLCs and tray in the current system caused a number of traffic jams as well as some confusion for new trained drivers. (Bär, et al., 2014), (Schäfer, 2015), (Göpfert, et al., 2012)
The problem of traffic jams and blockades in the supermarket is eliminated by restructuring the places where the empty SLCs and trays are collected and by introducing the order picker as mentioned in chapter 6.3.

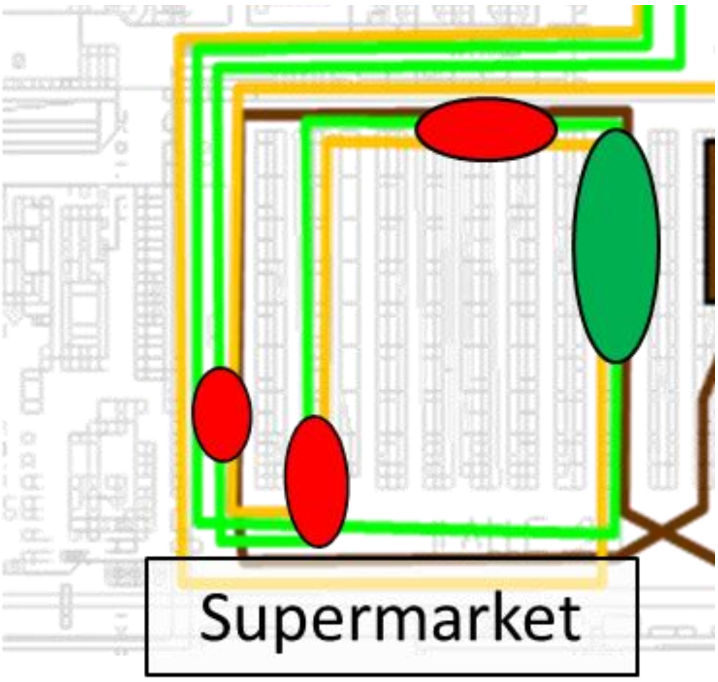

Figure 6-16: Layout of the supermarket in hall 20 before and after the optimization

Figure 6-16 is showing the general layout of the supermarket. Critical locations of traffic jams and blockades are marked in red, which are also the spots where SLCs and trays are collected.

Figure 6-17: The supermarket in before and after

Figure 6-17 is showing the supermarket. Pictures with the red border are showing the starting situation and those with the green borders the optimized solution. That optimization has improved working conditions for all trailer route system drivers. The new layout also increase the safety.

6.7 Low and High Runner

At MAHLE Filtersysteme Austria there are two types of lines, the high and the low runner lines. Low running lines are defined as production lines, which are producing a low number of products and are running only one or two shifts per week.

Originally the materials have been supplied in the supermarket of hall 20, blocking space for other needed material. To solve that problem an special trolley has been developed to store the material for those low running lines. These trolleys are placed near the production lines. As a result of this modification some refill channels can now be filled with high running materials.

6.8 Pre-defined stopping stations

For the trailer systems installed at MAHLE Filtersysteme the static system with pre-defined routes is used. This static routes have no pre-defined stopping stations. In literature, it is said that for well working pre-cycled systems pre-defined stopping stations and timetables need to be visible for the employees. (Klug, 2010)

The is-analysis as well as the weakness analysis shows that supply- and disposal systems were having waiting times up to 14 percent per shift, mainly caused by traffic jams. The average time loss at the supply system was one hour and five minutes and fifty-one minutes at the disposal systems.

First it is needed to define the stopping stations and mark them on the floor of the production areas. Afterwards the trailer system drivers need to be trained to use the new defined stopping stations.

In case of MAHLE Filtersysteme the place for stopping stations on the production floor was very limited. Therefore it is needed to decide if a stopping station is used for the supply or the disposal train. The higher handling time per line of the supply systems was the significant factor for the decision. The pre-defined stopping stations have been designated to the supply system.

For this thesis the stopping stations are just marked on the ground by adhesive stripes and not drawn with colour. The effect is that the stripes lasted only two months, so the suggestion is to draw the stations on the ground.

Figure 6-18: The success of pre-defined stopping stations

Figure 6-18 is showing the positive effects of introducing stopping stations to the trailer system in segment 15. In the company MAHLE Filtersysteme also some other segments are supplied and disposed by trailer systems. In most of the other segments, there are no stopping stations on the floor during this thesis, but segment 15 should set the new standard for trailer route systems at MAHLE Filtersysteme.
The positive effects of the stopping stations are recognisable in nearly no traffic jams anymore and an increased safety standard on the routes. The introduction

and acceptance of the stopping stations has nearly eliminated the waiting time of eleven percent of the disposal system. This is caused by the possibility for the disposal system to pass by the supply system. (Klug, 2010)

6.9 Poka Yoke

The concept solution for the elimination of mixing up different materials at one filling station is developed by the usage of Poka Yoke. Poka Yoke is Japanese and stands for avoid mistakes. Target of Poka Yoke is to create a one-hundred percent elimination of mistakes in production systems and lines. (Dickmann, 2009)

Poka Yoke are on the one hand side very simple elements to eliminate mistakes on the other side it is very difficult to create easy and understandable devices. For example an USB stick is can only one pre-defined position. This eliminates mistakes by using a special design. (Schäfer, 2015)

All involved parties where failures could occur shell accept solutions of Poka Yoke and support those to gain the needed benefit. Poka Yoke solutions are defined with geometrical or coloured solutions. The main point of the Poka Yoke philosophy is that the operator is realising early enough that a mistake can occur and stops the operation. The realization of this philosophy is based on a one-hundred percent control mechanism to avoid mistakes at the source of the mistake, by self-control during or following controls. (Schäfer, 2015)

During the is-measurement two material mix-ups occurred. At one occurrence the supply driver realized the mistake early enough. At the other situation which do not lead to a downtime of the production line, the mistake was recognized too late. That lead to a waste of time 24 minutes for the driver as he had to sort out the wrong sleeves. Driver used this time for sorting out the wrong sleeves.

Creating a geometrical solution for the supply drivers would lead to an extent the refilling process. As this is considered as waste a coloured solution is developed.

Figure 6-19: Mix-up of supplied materials during the is-measurement

Figure 6-19 is showing the real case of mixed-up sleeves during the is-measurement. The concept solution for MAHLE Filtersysteme is that the suppliers of the sleeves are painting coloured areas on the bags. Every bag with the same material number gets the same colour and different materials never get the same colour. For example, the bag of the short sleeves is coloured in red but the refilling station is coloured in yellow, so the driver gets a visible hint that the bag is wrong. Afterwards the driver needs to cut through a pre-defined space that is coloured. At least by the cut the driver is going to recognise the different colours.

Figure 6-20: Concept solution of Poka Yoke

Figure 6-20 is showing the concept solution for eliminating material mix ups with colours.

6.10 Standardisation of the processes

Standardisation is the unification of processes, types, forms and colours. One target of this thesis is to introduce standards to the trailer route system in segment 15. Furthermore segment 15 is used as the flagship segment for standardisation at MAHLE Filtersysteme. (Bär, et al., 2014)
Target of standardisation is to reduce the complexity of processes and its applications. To gain the best benefit out of standardized processes it is needed to interview all concerned employees. Therefore, this standardisation is following the philosophy of LEAN management by continuous improvement. (Klug, 2010), (Schäfer, 2015)
The standardisation of this thesis is following the method of 5S. This structured method tries to eliminate waste and increase efficiency as well as productivity. The 5S method was developed in Japanese production systems. The motivation of employees is going to be increased by a better organized working places, having positive effects on quality, environment and safety. The following five steps need to be passed to create new standards following the 5S method: (Bär, et al., 2014)

- Seiri – sort
- Seiton – set in order
- Seiso – shine
- Seiketsu – standardize
- Shitsuke – save and sustain

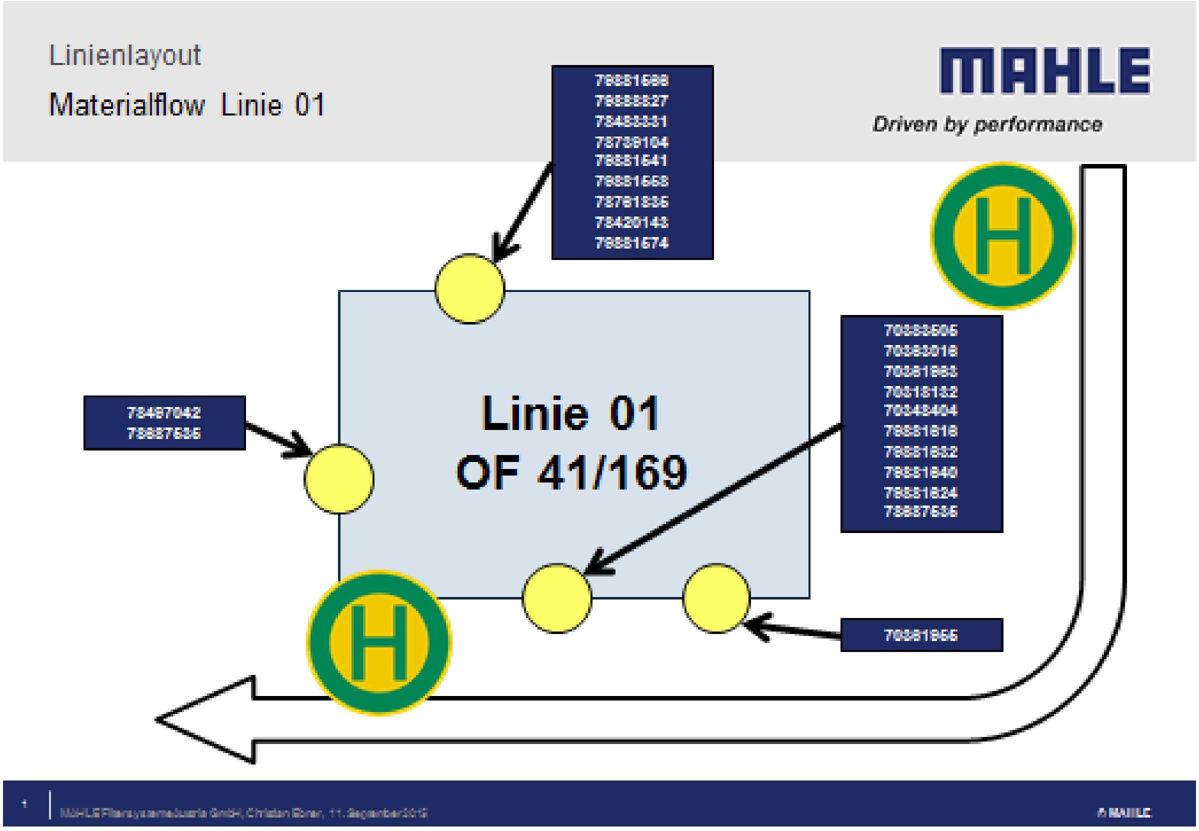

Figure 6-21: Standardized line layout on slides

Figure 6-21 is showing the developed sign of the line layout. These signs are going to be installed at every line. It contains the needed information for the supply drivers where the refilling stations are at the line and which material needs to be supplied where. Furthermore the signs includes the production line number and the name of the oil filter module produced at the line. The arrow shows the route of the trailer system with the installed stopping stations. If a new trained trailer route system driver forgets where he/she needs to deliver the material the signs is going to guide him/her. Target is to install such signs in the whole company, where the production lines are supplied by train.

7 Evaluation of the project

The solutions found during this thesis are based theoretical evaluations and tested practically. To evaluate these solutions it is needed to order parts, organize presentations and afterwards test them. The testing is very important, because only pilot tests can prove the theoretical evaluations. In addition unforeseeable problems can arise during particle tests. Furthermore well working tests often set new standards for the future.

7.1 Testing the order picker

To introduce the order picker first more supply trolleys are needed to be organized and placed on the new working place. The introduction of the order picker has parallelized the ordering and picking process. Than a second printer on the working place of the picker was installed. This installation eliminated unnecessary movements of 140 steps in one direction to reach the old printer. This is a time reduction of one minute and fifty-two seconds. Afterwards a training for the new system was organized.
The introduction of order picker reduces the average lap times by 26 percent. Therefore the trailer routes systems are able to run on faster cycle times and reach each line more often during one shift. The order picker, who is specially trained for this job and no more picking train drivers, now does the difficult process of picking the material. Figure 7-1 is showing the new collection points in the supermarket as well as an exemplary picking list. (Gudehus, 2010)

Figure 7-1: Collection points and picking list

7.2 Testing the combination of the two supply routes 2 & 3

The combination of the two trailer routes are going to lead to a higher utilization of the capacity of the system, as the supply of hall 24/25 is now done by one system. Furthermore combining the two routes leads to a reduction of traffic, which also increases the safety.
This combination was tested twice. The first test failed because line nine ran out of heat exchangers. Therefore the solution working with towers has been introduced to ensure the material supply for line nine. The second test has to be stopped after a short time due to a human error and not adjusted inventory ranges. Never the less enough data has been collected to do an evaluation. Figure 7-2 is showing the evaluation of the second test. This evaluation is showing that the longest time for one lap was 50 minutes. This is faster than the previous calculated 57 minutes and 45 seconds. Therefore it can be said that the combination of the two supply routes is a feasible solution.

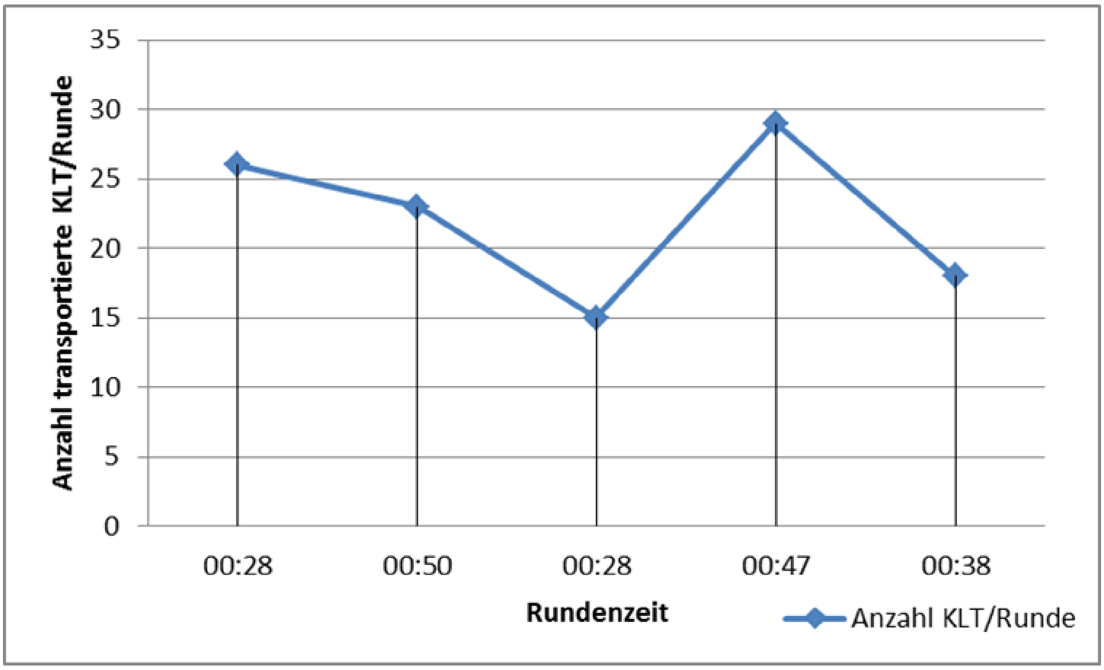

Figure 7-2: Evaluation of the test

The test also showed an increase of the utilization of the capacity of the trailer route system of 302 percent. During the test the parallelization of the processes and the system of order picker and one trailer route system driver worked very well. Figure 7-3 is showing the visual comparison of the utilization of the capacity. The picture on the left is showing the current loading of the system and picture on the shows the loading of the system during the test.

Figure 7-3: Utilization of the capacity of the supply trailer route system

The tests showed up new findings:

- The material provision in the supermarket and on the route needs to work without waiting time
- The trailer route system driver need to work according to regulations and ordering failures need to be eliminated.
- all seven inventory ranges turned out to be too small to fulfil the requirements of the combined system

7.3 Testing the standardization and stopping stations

For the test of the standardization it was needed to convince the segment leader of the benefits. After that was done the signs and stopping stations were marked on the ground by adhesive stripes. After the supply trailer system drivers were trained and introduced to the stations a huge amount of jams and blockades have been eliminated.

Figure 7-4: Line layout signs and stopping station

Figure 7-4 is showing some introduced standardizations in the production area.

7.4 Compare now with before

Comparing the starting situation with the end situation of this thesis the main mentionable points are going to be:

- Full supply change of line eleven to trailer route system
- Pre-defined stopping stations
- Increase of safety
- New working place
- Optimized supermarket layout
- Conceptual solutions for Poka Yoke and the disposal system
- Tests of several solutions
- Several analysis of processes

The points mentioned above are having several effects on the trailer route system. For example the supply system is running on a cycle time of below twenty minutes but is able to run in an hourly cycle time. The combination of the two supply routes is possible to perform with some small adjustments. The order picking process is working well and is recommended to maintain. For the introduction of an order picker the turnover time of SLCs needs to be bigger than half of a shift.

8 Conclusion

Main target of this thesis is to optimize the already installed trailer route systems at MAHLE Filtersysteme Austria in St. Michael ob Bleiburg. Segment 15 is used as the flagship for most activities as well as the warehouse.
This thesis is following the procedure of the DMAIC cycle. Therefore an analysis of the processes and process steps needs to be done. Afterwards the collected data needs to be evaluated and all kinds of waste are needed to be highlighted. The term LEAN management comes into account by classifying all different types of waste and categorize them into different types of waste.
Various improvements, suggestions and concepts are developed in this thesis, which are going to improve the working conditions, the safety and the control of the working processes. For example for one line the supply process is changed. Another example is saving one working place at the production line and introducing a new job at the warehouse on the other hand.
This thesis is focusing on the one hand side on the work processes, safety and working environment and on the other hand on the development of various improvements, work simplifications and general optimizations.
The majority of the improvements and developments have been tested and evaluated.

Chapter 1 describes the MAHLE group with its growth and the plant in St. Michael ob Bleiburg more in detail.

Chapter 2 is dealing with the starting situation, the procedure and the target of the thesis.

Chapter 3 describes the theoretical background of Supply Chain Management, logistics, internal transport systems and the philosophy of LEAN management.

Chapter 4 shows the measurements and their evaluation. Furthermore the trailer route systems and their parts are going to be explained. The layout of the supply- and disposal routes are discussed within this chapter.

Chapter 5 is focusing on the supply- and disposal processes. Main weaknesses are categorized in tables and solutions are described briefly.

Chapter 6 is describing the different improvement solutions developed during the project time at MAHLE Filtersysteme. Many of these developed approaches are implemented and are improving the processes.

Chapter 7 is comparing the starting situation with the situation after implementing the improvements.

Following activities have been identified during this thesis.

Short term activities:
After the positive effects of the implementation of line layout signs and stopping stations in segment 15 the introduction of this standardizations should be done in all segments of MAHLE Filtersysteme. Push the standardisation through all segments by adopting the line layout signs to all other production lines. Train all employees to the new standards. Implementation of stopping stations clearly marked on the floor through all production halls.
Include defined stopping stations already in the layout of new production lines.

Mid term activities:
Introduction of a modified version of LYDIA, a voice-operated picking and guiding system already in use of some segments of MAHLE Filtersysteme. As the current version does not allow parallelization of the picking and ordering process a modification of the program is necessary.
An optimization of the refilling channels in the supermarket in hall 20 shell also be initiated by this thesis.

Long term activities:
Implement the developed process for the disposal system. By the usage of this developed process the trailer system as well as the throughput of the boxes can be monitored easier. Furthermore an optimization for the needed deliveries can be done by analysing data stored in the ERP system.
Finally follow the vision given by the headquarter in Stuttgart to supply and disposal all production lines by trailer system.

9 Index

9.1 List of literature

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9.2 List of Figures

9.3 List of Tables

9.4 List of Abbreviations

BPMN	Business Process Model and Notation
CIP	Continuous Improvement Process
DMAIC	Define Measure Analyse Improve Control
ERP	Enterprise Resource Planning
Q-Circle	Quality Circle
SAE	Society of Automotive Engineers
SAP	Systeme Anwendungen Produkte
SLC	Short Load Carrier
TPS	Toyota Production System
VDA	Verband der Automobilindustrie

10 Appendices

10.1 Published short text (Deutsch)

Der firmeninterne Transport von Materialien zu Produktionslinien sowie deren Fertigteilabtransport wird bei Zulieferfirmen im Automobilbereich immer mehr von Routenzugsystemen durchgeführt. MAHLE Filtersysteme Austria in St. Michael ob Bleiburg nutzt diese Routenzugsysteme bereits in einigen Segmenten, um Produktionslinien mit Materialien zu versorgen sowie Fertigteile abzutransportieren. Dabei muss zwischen Materialversorgungszugsystemen und Fertigteilabtransportzugsystemen unterschieden werden. Der Unterschied liegt in der Beladekapazität, welche sich durch verschiedene Längen ergibt. Eine optimale Auslegung der Zugrouten wird durch das historische Wachstum der Firma erschwert.
Die Vorteile dieser Routenzugsysteme gegenüber Staplern sind beispielsweise eine Erhöhung der gesamten Arbeitssicherheit, ein größeres Transportvolumen pro Fahrt und die Möglichkeit der Bereitstellung von Materialien in Kleinladungsträgern.
Um diese Vorteile bestmöglich nutzen zu können, müssen gewisse Rahmenbedingungen erfüllt werden. Hierzu zählen vordefinierte Haltestellen für Routenzugsysteme in den Produktionsbereichen, eine angepasste Auslegung der Bestandsreichweiten an den Produktionslinien sowie im Lager. Des Weiteren müssen eine Standardisierung der Arbeitsabläufe und eine Parallelisierung von Prozessen erfolgen.
Die Parallelisierung des Bestellprozesses an der Produktionslinie mit dem Kommissionierprozess im Lager führte zu einer drastischen Reduktion der Staubildung im Lager, zu schnelleren Rundenzeiten der Routenzugsysteme und zu einer Erhöhung der Sicherheit im Lager.
In dieser Arbeit werden Problemstellungen aufgezeigt, evaluiert und Lösungen durchgeführt sowie angeregt. Ein EXCEL-File wurde entwickelt, um den Materialbedarf je Linie aufzuzeigen. Des Weiteren kann mit dieser Tabellenkalkulation der benötigte Platzbedarf je Linie auf den Materialversorgungszugsystemen ermittelt und mögliche Rundenzeiten berechnet werden. Haltestellen wurden an geeigneten Plätzen geschaffen und eine Standardisierung durchgeführt. Letztlich wurde eine konzeptionelle Lösung für eine Reduktion der Hebegewichte unter Berücksichtigung der Ergonomie entwickelt und getestet.