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Warehouse processes improvement for Enterprise Resource Planning implementation

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Bachelor's thesis
May 2019
Technology, communication and transport
Degree Programme in Logistics Engineering

Jyväskylän ammattikorkeakoulu
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jamk.fi

Description

Author(s) Tolstunova, Anastasiia	Type of publication Bachelor’s thesis	Date May 2019
		Language of publication: English
	Number of pages 97	Permission for web publication: x

Title of publication
Warehouse processes improvement for Enterprise Resource Planning implementation

Degree programme
Degree Programme in Logistics Engineering

Supervisor(s)
Franssila, Tommi; Turunen Marjo

Assigned by
Fries Kunststofftechnik GmbH

Abstract

Nowadays, companies strive to achieve accuracy, thoroughness and efficiency in operations. Disruptions can lead to delays, longer waiting times and, consequently, to unsatisfied customers. Thereby, every enterprise endeavours to avoid these failures in order to maintain its position in the market.

Throughout the expansion and development of an organisation, it becomes increasingly arduous to control all internal processes without the appropriate tools and a well-designed plan. Therefore, the main target of the work was to improve warehouse operations and combine the resulting solutions with the ERP system in Fries Kunststofftechnik GmbH. It was essential to determine the reasons for the inefficient use of the storage space and provide improvement decisions to accomplish the objective. Furthermore, the reflection of the warehouse operations in the ERP system was supposed to be established and expounded. The research was conducted using methodological triangulation method to minimize biases and any predetermined results. The causes of the problems were detected by dint of a root-cause analysis method based on the information gathered during participant observations, in-depth interviews and content analysis. Since the optimization was carried out in terms of space and time, solutions were announced separately. As a result of the space amelioration, detailed warehouse schemes were introduced and divided into zones in accordance with the names and categories of goods. Regarding time optimization, the generated schemes were displayed in the ERP system employing alphanumeric zones. At the management stage, control tables were executed. To get rid of congestion, it was proposed to hire new employees. This study and results can contribute the case company to reduce operating time and enhance performance. In addition, internal operations can be verified and controlled electronically.

Keywords/tags (subjects)
Warehouse processes; storage systems; inventory management; warehouse optimization; Enterprise Resource Planning

Miscellaneous (Confidential information)

Contents

Figures

Tables

1 Introduction

1.1 Components of a company's success

Every company struggles to take a leading position in the local or global market, depending on the size of the enterprise and, consequently, development opportunities.

Currently, most of the entities have their own warehouses for storing goods that have been produced or acquired. Hence, organisations that are engaged in logistics are not an exception. Thus, in order to build up a sustainable and successful company, internal components such as production if there is one, warehouse processes, stock management should be very well organised.

Warehouses are the nodes supporting a company's supply chain strategy. They strongly influence the maintenance and costs of the network. Failures in storage and shipment at the right time in the right quality and quantity will drive to customer dissatisfaction. (Grant, Trautrims & Wong 2015, 78.)

To unite and control all inner elements, a company requires sufficient business process management software that can facilitate to overcome potential obstacles and comply with the firm's needs and requirements.

1.2 Development of Fries Kunststofftechnik GmbH and its products

Fries Kunststofftechnik GmbH was founded in 1896 as a supplier of paper cones for the textile industry, and since then a number of fundamental changes have occurred. FRIES is a family business in the third generation, now concentrating on the manufacturing of goods from plastic. Approximately 4 000 tons of plastic granulate is processed annually. The enterprise, including its subsidiary CupConcept Mehrwegsysteme GmbH, has two sites in Austria and seven in Germany with 170 employees. The cumulative revenue of the company reached 27 million euros in 2018.

The company's competence comprises four strategic segments: packaging, gastronomy, industrial baskets and workpiece carrier systems, as well as technical parts (see Figure 1).

Figure 1. Four strategic segments in FRIES (retrieved from FRIES Kunststofftechnik GmbH, Products)

In relation to packaging, the company’s barrels, canisters, buckets, and cans are used for transportation of food, hazardous materials, pharmaceuticals, chemicals or for storage of potentially explosive atmospheres. In the gastronomy field, FRIES is the European market leader in commercial dishwashing baskets. Dishwashing baskets are utilized worldwide in renowned hotels such as Burj al Arab in Dubai, as well as at the Singapore Airlines Business Lounge. They serve for washing, storage and transportation.

Industrial baskets und workpiece carrier systems are applied in the industrial parts cleaning. For example, pieces of aircraft turbines of the Air France machines are cleaned with the help of industrial racks of FRIES.

For its own subsidiary CupConcept, the enterprise produces reusable cups for major events such as rock concerts, festivals and soccer stadiums. CupConcept distributes the cups by providing an all-in-one service package, including washing and logistics.

The success of the company involves ongoing investments and competent, dedicated employees who are working for the good and prosperity of the company. (FRIES Kunststofftechnik GmbH, Company and history.)

1.3 Production technologies in Fries Kunststofftechnik GmbH

Production in the case company includes two fields: “Blaserei”- extrusion blow moulding production and “Spritzerei”- injection moulding production.

Extrusion blow moulding is a section where canisters, barrels and some technical parts are manufactured. Two types of machines are employed in this area. A canister was taken as a sample of the product produced.

Starting with the first machine type, a process launches from transferring of new material, recycled material and colour to the mixer, where all three components are jumbled. Homogeneous material (plastic) is flowing through a heated cylinder directly between the forming plates. Further, the forming plates close, a blowing station goes down, and holding forceps keep surplus material. Once the forming plates open, the blowing station goes up, and the holding forceps kept the canister. The fourth step involves moving of the forming plates back to the initial position and racks towards the canister in order to get rid of surplus material. The canister is demonstrated from the other side at this stage. Last two actions in this cycle process are cooling, testing of weight and sealing. The sequence and basics of the process are presented in Figure 2.

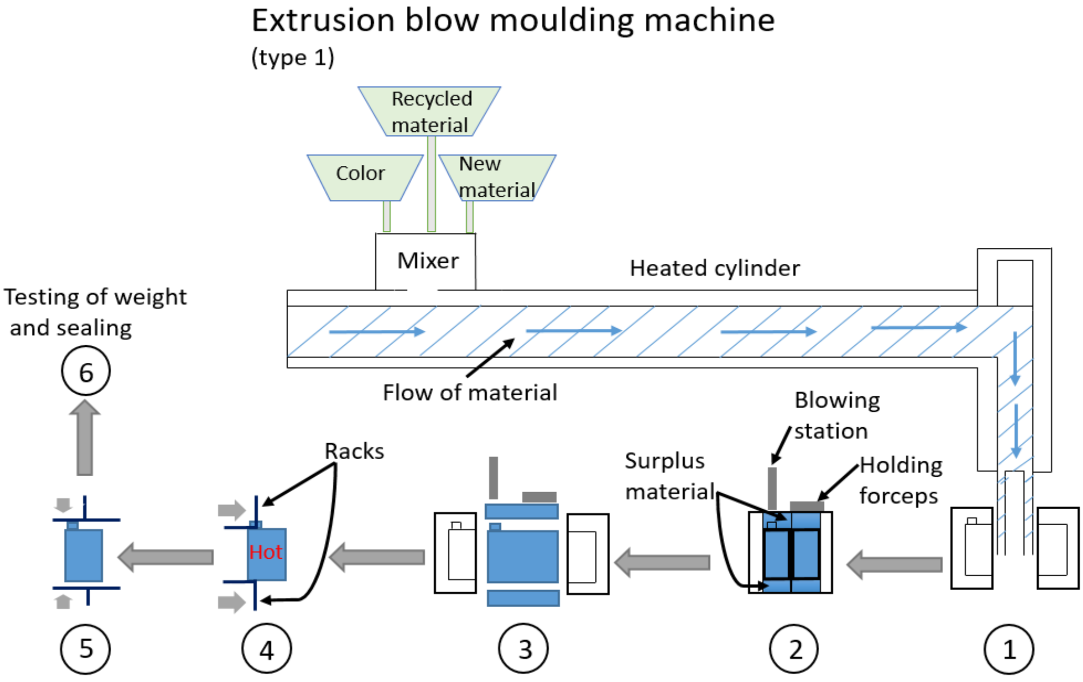


Figure 2. Functional diagram of the extrusion blow moulding machine (type 1)

A process of the machine of the second type commences the same way as the machine of the first type. However, there is one fundamental distinction before the first step. Homogeneous material (plastic) is flowing through the heated cylinder and is stored in a material buffer. There is a shutter that keeps the material while one canister is produced. One more difference is that the canister is manufactured upside down, thus the blowing station is located from below. In addition, manpower is required at the fourth stage. A worker removes the canister from the holding forceps and disposes it in the cooling station, which is respectively the fifth step. Ultimately, testing of weight and sealing is carried out in order to forward the article to the packaging zone. The sequence of steps of the machine of the second type is shown in Figure 3.

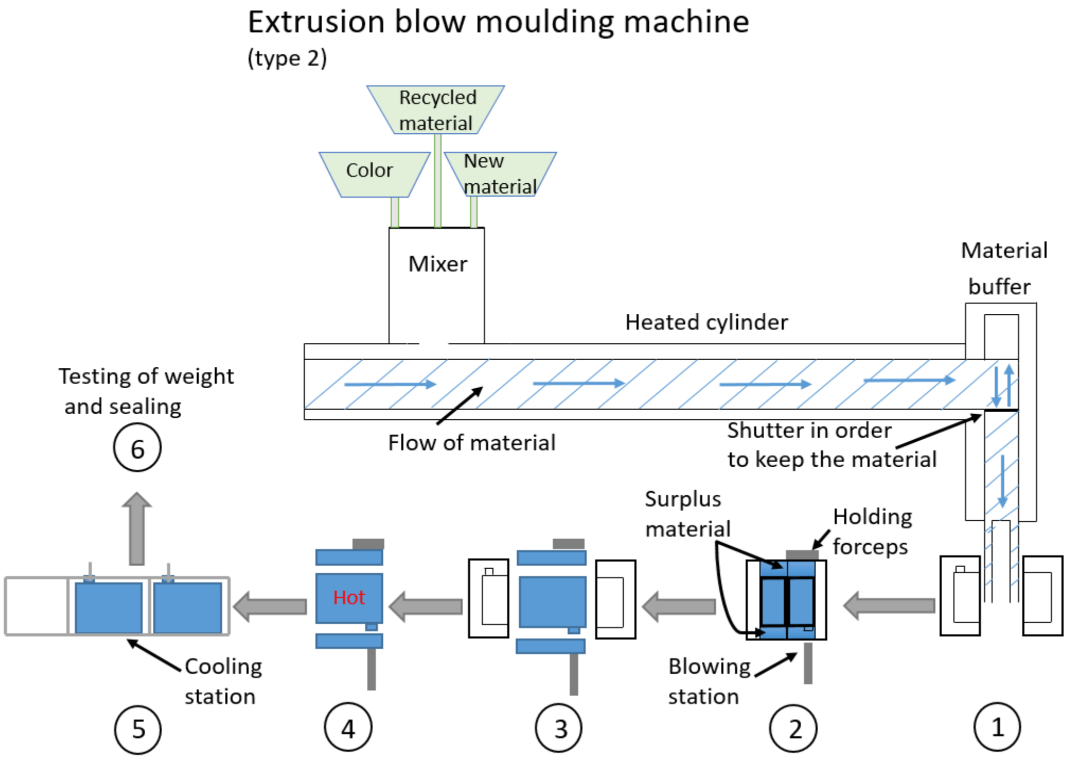


Figure 3. Functional diagram of the extrusion blow moulding machine (type 2)

In injection moulding part, there are several machines of different sizes, which are intended for production of lids, racks and baskets for different types of glasses and baskets up to 30 litres, dishes and cutlery.

Moreover, this part of production manufactures plastic cups with labels for various kinds of events and plates that can be attached to the glasses.

A lid was taken as a sample of the manufactured product. A working process starts from a feeder hopper, through which the material (plastic) passes inside the cylinder. In the meantime, a screw is rotated due to the motor in order to move the material towards an injection moulding form. At the second stage, the material inside the screw is melted by means of the heater, is moved and pushed into the closed moulding form under high pressure. Injection moulding form is closed during cooling. After completion of cooling, the injection moulding form opens and a ready-made product is transferred to a conveyor belt. The final step is testing of weight and measurements before delivering the item to the packaging area. Since this is a cyclic process, all the steps described are repeated. The principles of operation of the machine are displayed in Figure 4.

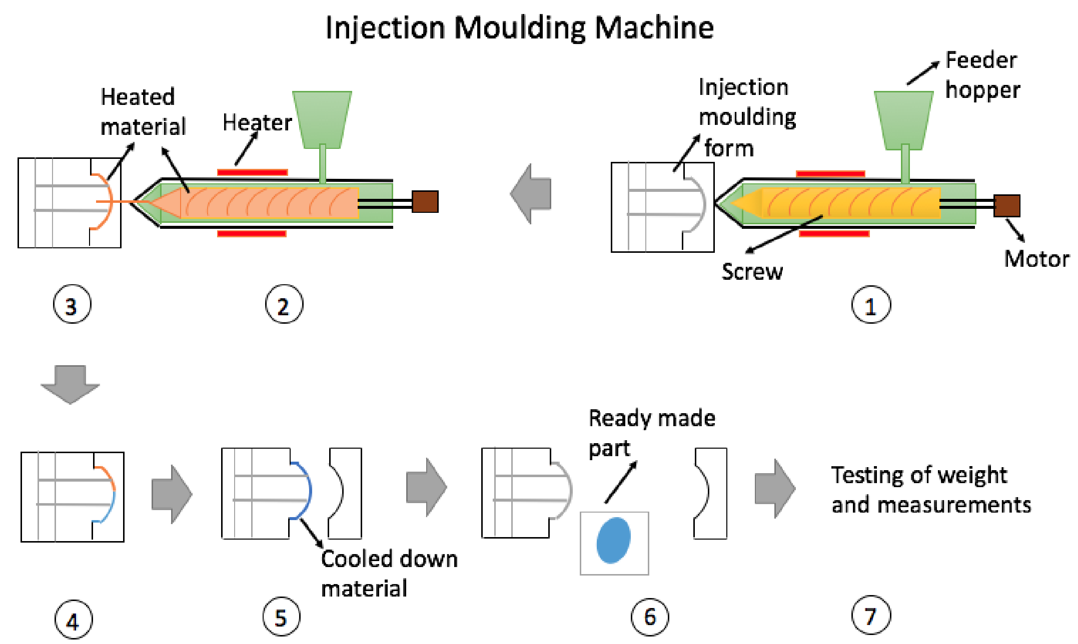


Figure 4. Functional diagram of the injection moulding machine

1.4 Warehouse utilization in Fries Kunststofftechnik GmbH

A general overview of the storage space in FRIES is given in Appendix 1. Warehouse areas in the case company are utilized in the following way: they are divided into two key zones according to the major production fields.

Repository for products manufactured in the extrusion blow moulding area has three floors: cellar, ground and mezzanine floor. A closer look at the mezzanine structure is taken in sub-chapter 3.2 Most common types of warehouse storage systems. Only on the ground floor pallets can be stacked on top of each other, and mainly because of the height of eight meters. Ground and mezzanine floors are demonstrated in Appendix 2 and in Appendix 3. The cellar floor is presented in Appendix 4.

In the warehouse constructed for the goods made in the injection moulding zone there are three floors: ground, first and second (see Appendix 5, 6 and 7). On the first floor, in specially restored premises, the height of which exceeds five meters, pallets can be stacked on top of each other. These areas are marked with red circles in Appendix 6.

Likewise, yard area called “Hoflager” is employed to store articles from the injection moulding zone. The key reason for this is the number of items produced. It is assumed that “Hoflager” has no roof, and hence, all pallets can be loosely placed above each other. This storage is illustrated in Appendix 8.

The case company has “Zwischenlager” in order to keep spare parts for the assembly. Repository for these needs is displayed in Appendix 9.

In each of already mentioned warehouses, stamped euro size pallets (1200 x 800 mm) and standard size lightweight pallets (1200 x 1000 mm) are used. Figures 5 and 6 show both types of pallets. “Zwischenlager” also utilises storage shelves, which are presented in Figure 7. In “Spritzerei” warehouse there are some pallet places for tools that are applied in production. This pallet place is depicted in Figure 8.

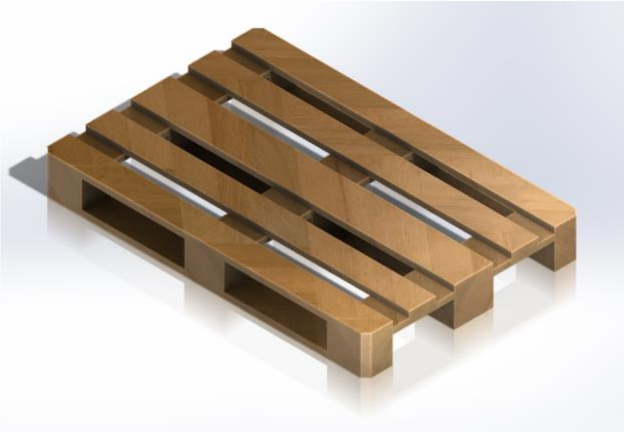


Figure 5. 3D model of a stamped euro size pallet (1200 x 800 mm)

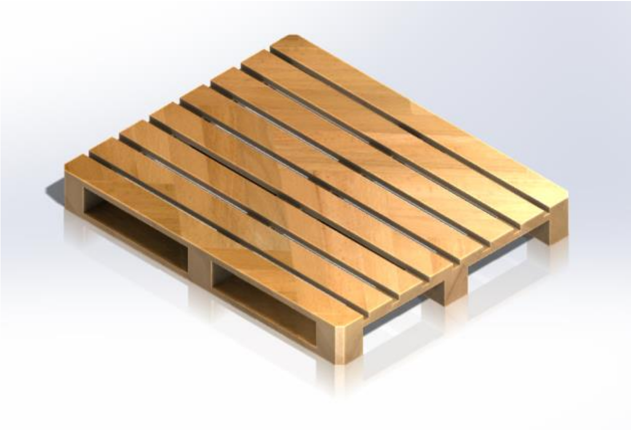


Figure 6. 3D model of a standard size lightweight pallet (1200 x 1000 mm)

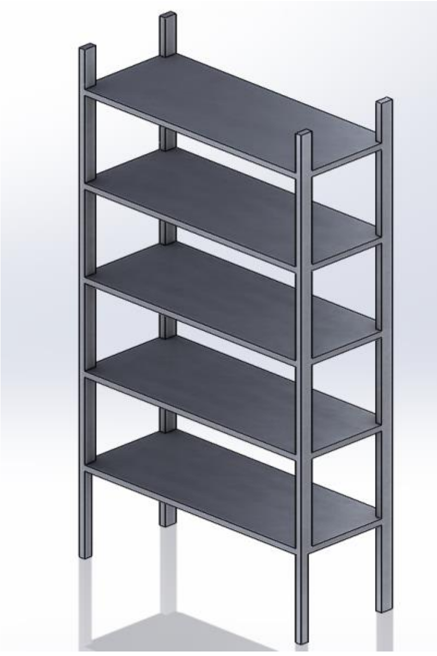


Figure 7. 3D model of a storage shelf

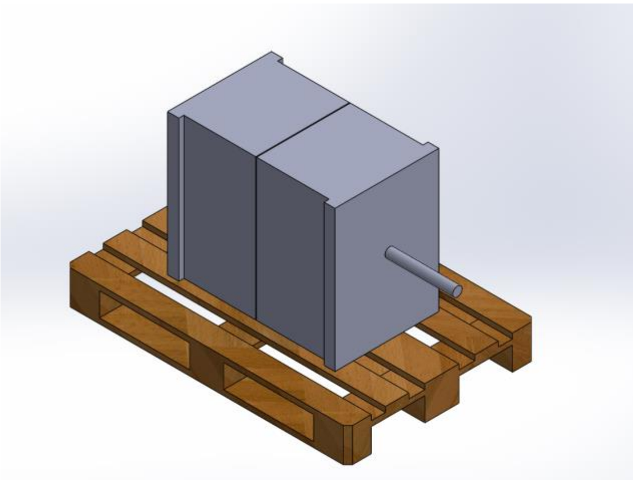


Figure 8. Pallet used to store a tool in “Spritzerei” warehouse

1.5 Research objectives and questions

The main aim of this thesis work is to optimise warehouse processes in the case company. More efficient and optimal usage of warehouse space, implementation of tracking tools to be aware of goods’ location and faster delivery of items are among expected outcomes. In connection with the construction of a new warehouse, more space for manufactured products will appear.

In order to combine and better control warehouse processes in FRIES, a new ERP system with a higher integration of warehouse processes will be introduced.

To reach the assigned goals of this case study, the following research questions were defined:

The key research question is:

1. What actions should be taken to optimize the warehouse and its processes?

The supporting questions are as follows:

1. How was it determined that storage space is used inefficiently?
2. How was it found that the delivery of goods on the first and second floors takes too much time and how can it be reduced?
3. What systems can be applied to be aware of the articles´ locations in the warehouse?
4. How did it turn out that the case company does not have enough free space and how can the room for storage be increased?

Receiving answers to these questions, it was supposed to discover causes of the problems in the warehouse and its processes along with the possible solutions.

2 Research basis

Research is an intensive and focused search for knowledge and understanding of social and physical phenomena (Kumar 2008, 1).

In other words, research is a process of planning, executing and investigating in order to find reliable answers to the specific questions (Ghauri, Grønhaug 2005, 3).

2.1 Types of research methods

Types of research methods are divided into different categories, depending on the nature and purpose of the study and other characteristics.

Quantitative vs Qualitative

Quantitative research methods employ data collection suitable for conducting statistical analysis. Gathered data can be used in creating tables and graphs, and resulting numbers can be converted to percentages or any other appropriate numerical form for the researcher.

Qualitative research methods, in comparison, utilize ways of collecting data, excluding numerical parameters, and can provide specific important details concerning the topic of interest. Qualitative data presents visual figures and information that is designed to give answers on questions starting with “why” and “how”. (McLeod 2017.)

A principal distinction of quantitative and qualitative research is the environment in which it is held. Since quantitative studies tend to control extraneous variables, they are carried out in the laboratories. In order to understand events properly in a qualitative approach, information regarding them should be collected in the natural surroundings. (Monteleone, Langstaff 2014, 145.)

Descriptive vs Analytical

The main goal of descriptive research, known in social sciences as ex-post fact research, is to describe state and affairs. Control of variables is not characteristic for this study. Investigators can report only what has happened and what is happening using this method.

In the analytical research, facts and already available information should be utilized and analyzed in order to make evaluation of the material. (Kumar 2008, 6.)

Applied vs Fundamental

Applied research seeks to find a solution for the problem by enriching the field of application of the discipline. Several disciplines are frequently combined to solve an issue. This method tries to display how things can be changed, while fundamental research is aimed to explain why things happen.

Fundamental, which is also known as pure research, is intended to illustrate the theory, enriching the foundations of the discipline. Pure research explores the problem from the focus of the discipline. (Kumar 2008, 7.)

Empirical vs Conceptual

Empirical research relies on experience. This study is based on the data that allows drawing conclusions that can be verified through experimental studies or observations. Empirical research is applied when evidence is required that certain variables affect others. Likewise, it is significant to create a working hypothesis about possible outcomes from the beginning.

Conceptual research, in turn, is associated with some abstract ideas and, as a rule, is used by philosophers to develop new concepts or rethink existing ones. (Kumar 2008, 8-9.)

Experimental vs Non-Experimental

An experimental type of research launches from the creation of a hypothesis that the study would like to test. Collected data is used by the researcher to establish a cause and effect relationship between two variables.

Non-Experimental research, on the other hand, does not require the formation of a hypothesis, and data captured during the study can be utilised to describe relations without showing their functional correlation. (Kumar 2008, 9.)

2.2 Data gathering methods

There is a number of various types of data collection methods. Each has its upsides and downsides, and at the stage of selecting one among the others, time frames and final goals of the work should be taken into account.

Figure 9 displays the qualitative and quantitative data research methods.

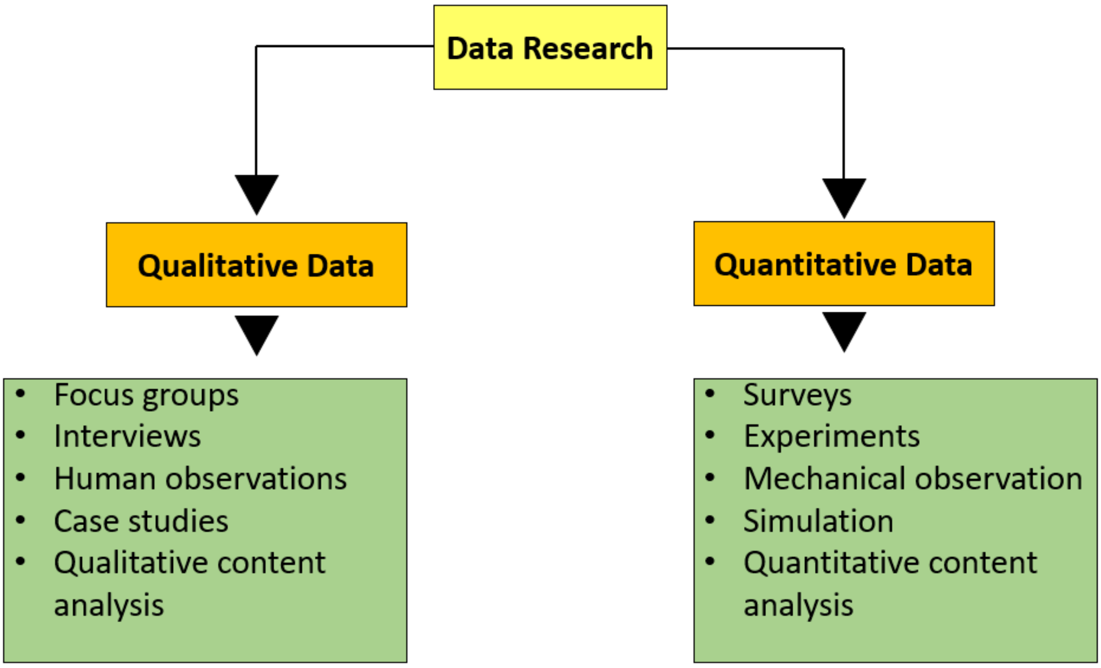


Figure 9. Data research methods (adapted from Bamberger 2000, 11; Gibbs 2007, 2)

Focus groups

Focus groups include from 8 to 12 people with similar characteristics corresponding to the evaluation. A discriminative feature of focus groups is the interaction of participants to generate ideas that otherwise would hardly have appeared. This method enables to monitor the dynamics of the invited group and understand the behaviour of the respondents, following their discussion and attitude. (Frechtling 2002, 52-53.)

Interviews

Interviews as ways of capturing data are selected when participants´ opinions are meaningful and influence on the success of the final result. Interviews can be held in-person or on the telephone. Evaluation research employs two types of interviews: in-depth and structured interviews. In the former type, interviewers do not stick a fixed form and tend to encourage respondents to give open answers on prepared questions. In the latter type, the main objective is to get answers to carefully formulated questions. (Frechtling 2002, 50-52.)

Human observations

Observations can be of the following types: direct or participant observations. During participant observations, a researcher takes part in the actions and activities not only to observe from the side but also to receive data from the first hands. Direct observations, in turn, are conducted without intervention and participation. (Crossman 2017.)

Information can be gathered on a wide range of processes and operations. Observations can be beneficial both in the initial and final stages of evaluation. At the initial stage of observation, it may be useful to determine whether the project is going to be used as it was planned or not. As for the final stages, observations are utilized to define if the project is successful in the future or not. (Frechtling 2002, 55.)

Case studies

A case study is chosen when the phenomenon is studied in-depth. By phenomenon, a project or a program is meant. Case studies permit to constrict a very wide area of research into one easily researched topic. This method can supply with a broad picture of the project since it is carried out in real conditions. (Frechtling 2002, 61; Yin 2003, 4.)

Surveys

Surveys are appropriate tools for obtaining information on a wide range of matters and are applied when information should be received from large groups. Main components of surveys are questions and responses. Most often, interviewed are offered to choose answers from a diapason of predetermined answers, but sometimes “open-ended” replies are also included. Answers may be presented in a rating from 5 to 1, from “agree” to “disagree” or provide different categories for selection. Surveys can be held both electronically and using paper forms. It depends primarily on the complexity of issues, time frames and investment opportunities. (Frechtling 2002, 49-50.)

Experiments

Experiments provide a measurement of things. Such attributes as controlling the variables and creation of cause-effect relationships are characteristic of experiments.

They are meant to be objective, and the researches' opinions should not affect the results. (McLeod 2017.)

Mechanical observations

In order to collect data during mechanical observations, different types of machines are utilised. The results are subsequently explained by researchers. Among the machines one can discover the following: electronic checkout scanners that record purchase behaviour, voice pitch meters that measure emotional reactions and eye-tracking analysis, which is used to investigate people watching an advertisement. The most frequent method of mechanical data capturing is a video camera. (Malhotra, Nunan, Birks 2017, 289-292; Methods and Techniques of Observation 2017.)

Simulation

Simulation is an imitation of the operation of a real process over a certain period of time and is aimed to inquire what-if questions about the real system. The simulation includes the creation of artificial system history and observation of this history to make conclusions regarding the operational characteristics of the represented system. They are also used in the design of real systems. (Banks 1998, 3-4.)

Content analysis: qualitative and quantitate

Content analysis is a method of converting qualitative data into quantitative data for statistical analysis by counting or using numbers.

Qualitative Content analysis includes qualitative and quantitative steps of analysis and stands for common research criteria for both research methods. Quantitative content analysis is applied for the interpretation of written communication by means of software applications. (Krippendorff 2004, 87; Lock, Seele, 2015.)

2.3 Root cause analysis methods

The collected information should be processed, and analysis methods are employed for this purpose.

Root Cause Analysis is a powerful tool that helps to define existing barriers to betterment and identify specific areas in which improvements can be most beneficial (Wilson, Dell, Anderson 1993, 3).

At first, it is essential to understand a problem by creating a picture of business processes. Flow charts and cross-functional flow charts are applied for step-by-step process descriptions.

Flow chart

A flowchart is a graphic representation of data flow through processing systems. A flowchart, which is also called a diagram, shows the sequence of operations in the system. Flowchart symbols are well known in many disciplines, and hence, instructional developers can convey a lot of information efficiently, accurately and concisely. (Flowcharts, Storyboards and Rapid Prototyping, 90-91; Mahdi 2013, 11-12.)

When constructing a flowchart, 6 basic symbols are usually used (see Table 1).

Table 1. Basic symbols used in flowcharts (adapted from Mahdi 2013, 12)

Symbol	Function
Start/ Stop	Rounded box indicates the beginning or end of a flowchart.
Process	A rectangular box represents an action that is controlled within the process.
Input/ Output	A parallelogram is used to display any Input / Output operation.
Decision	A diamond shape is a decision point in a process that requires a "yes" or "no" response.

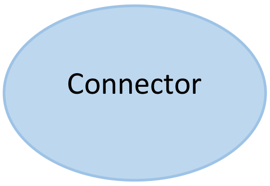
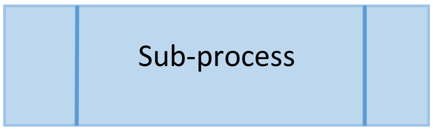
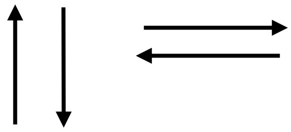
	A flow chart can be constructed without a reserve flow or intersecting lines with the help of a connector.
	This shape is used to divert to another flowchart in order to complete a task before returning to the original flowchart.
	Flow lines show the direction of the flow.

Figure 10 illustrates a flowchart example.

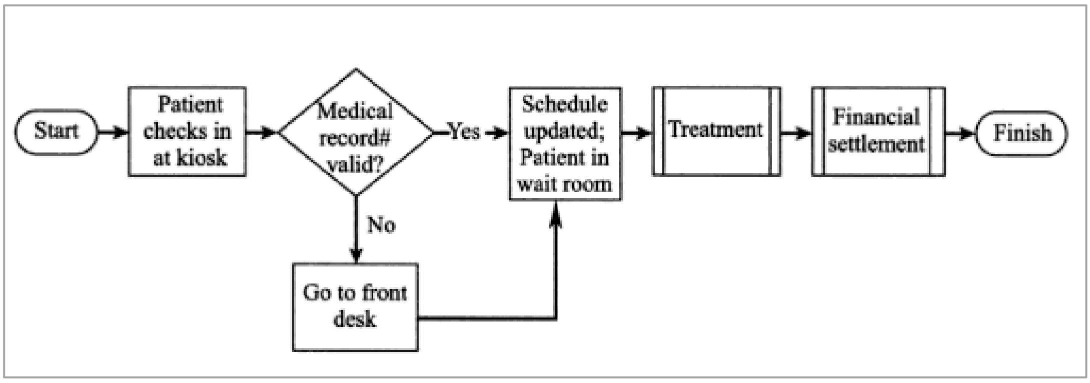


Figure 10. Flowchart example (retrieved from Langabeer 2008, 77)

Cross-functional flowchart

A cross-functional flowchart, also called a Swimlane diagram, is used to demonstrate the relationship between processes and functional units (see Figure 11). The swimlanes or bands in a flowchart represent functional units, such as departments or positions. Each shape describes a step in the process that is placed in the swimlane that correspond to the functional unit responsible for that step. (Halseth 2008, 5.)

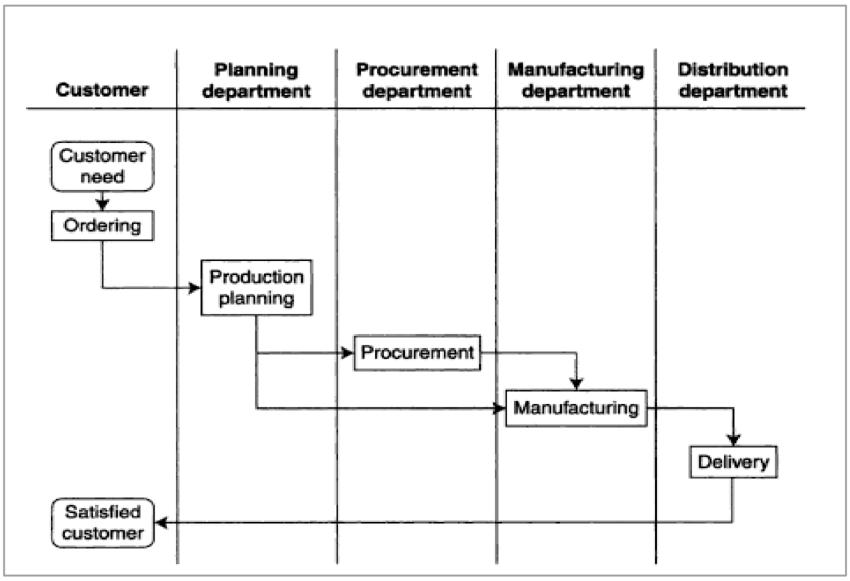


Figure 11. Cross-functional flowchart example (retrieved from Andersen 2007, 52)

After clarifying business processes, the next important matter is the use of analysis tools to identify the root causes of the issues found. Affinity chart, Fishbone diagram, Five Why analysis, Drill down pie chart, SWOT analysis are suitable methods for these purposes.

Affinity chart

Affinity chart or diagram is a brainstorming tool that is also known as Kawakita Jiro (KJ) method. This chart is a powerful technique for grouping and comprehension of information and is based on group work to gather more opinions and ideas.

The basic principle of an affinity diagram is first the formulation of the concern, and then brainstorming of ideas, which will be grouped according to related groups. (Charantimath 2003, 96.)

Figure 12 displays an Affinity chart example.

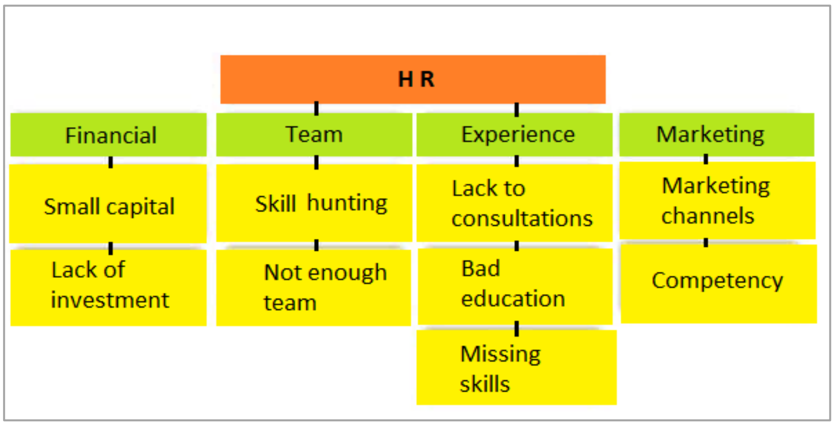


Figure 12. Affinity chart example (adapted from Elmansy 2016)

Fishbone diagram

Fishbone diagram, also called the Ishikawa diagram, is an analysis tool that ensures a systematic look at the causes and effects that contribute to these effects. According to Watson (2004), Fishbone diagram may be referred to as a cause-and-effect diagram due to its function.

Figure 13 demonstrates a Fishbone diagram example. Long horizontal arrow is called the spine of the Fishbone diagram and it is pointed to the main problem. Primary causes are placed in white rectangles and directed to the spine of the diagram. Short horizontal arrows indicate causes contributed to primary ones, while arrows perpendicular to them represent sub-causes.

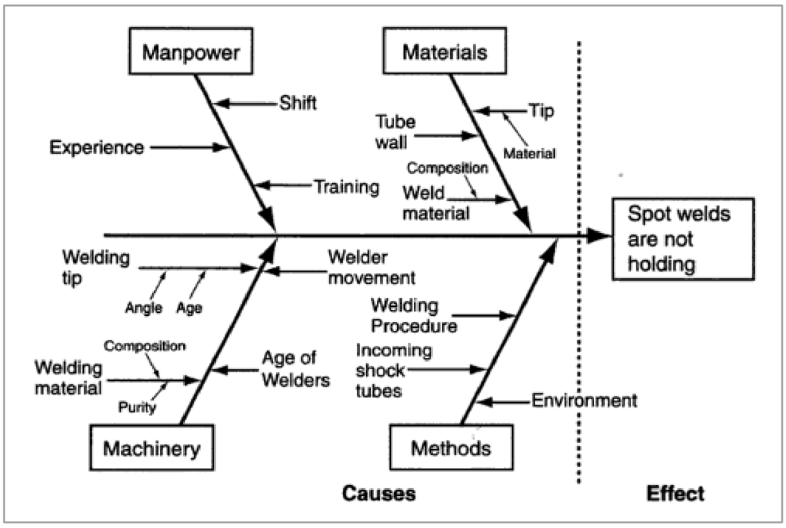


Figure 13. Fishbone diagram example (retrieved from Fryman 2002, 199)

Five Why Analysis

A “Five Why Analysis” is a method that is applied to recognize the root cause of a problem by asking “Why?” questions five times (see Figure 14). The analysis starts with asking first “Why?” question to the stated problem. Then, the next “Why?” question is inquired to the obtained answer, and following the same principle until the root cause will be detected.

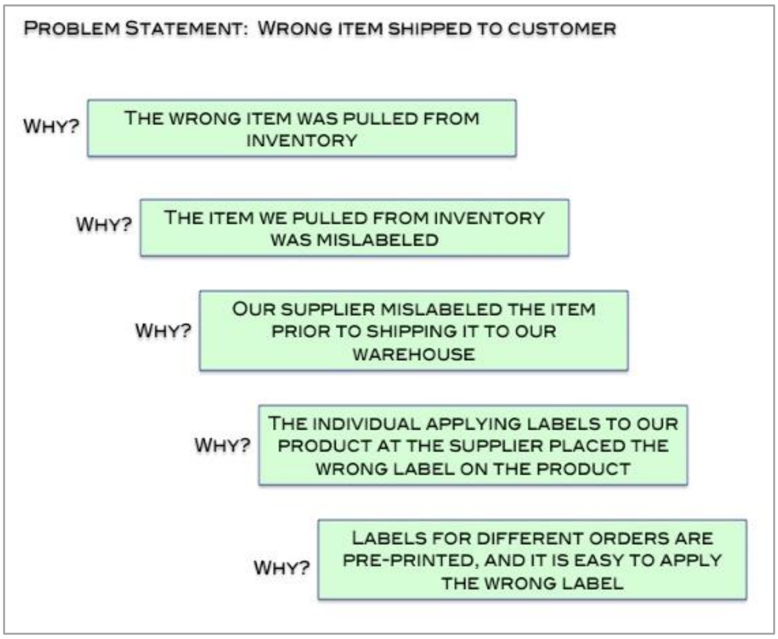


Figure 14. Five Why Analysis example (retrieved from DMAIC Tools 2019)

Drill down pie chart

The main idea of a Drill down pie chart is creating two related pie charts. Since the former provides a general overview with hidden details, the latter supplies with an in-depth view of the selected value.

Example of a Drill down pie chart is given in Figure 15.

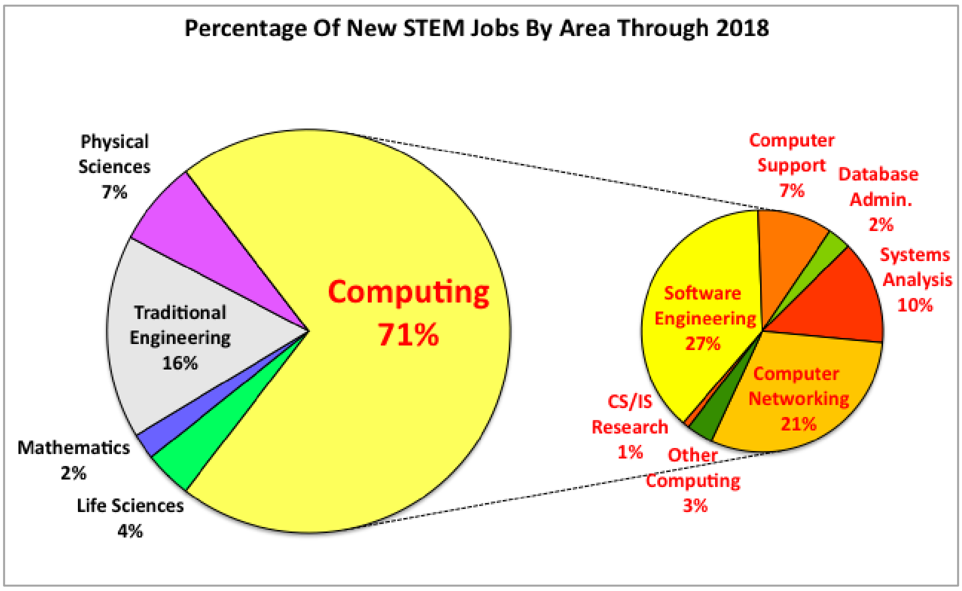


Figure 15. Drill down pie chart example (retrieved from The Market for Computing Careers 2010)

SWOT Analysis

SWOT Analysis is a decision-making tool and refers to strengths, weaknesses, opportunities and threats (see Figure 16). This tool is used to analyze both internal and external factors affecting internal functioning in a row with external factors that depend on the environment in which it is developing. (Seth 2015, 5.)

SWOT analysis is easy to perceive because it is a simple diagram without mathematics. This tool is visual and can be applied to a person, a team and an enterprise. (Sarby 2016, 3.)

Figure 16. SWOT example (retrieved from Competitive Futures 2015)

2.4 Lean Six Sigma method

Lean Six Sigma was developed by Motorola in 1986 and is currently used in a number of industrial sectors (Levy, M. 2018).

This method is a data-based approach that brings to fact-based solutions by means of statistical techniques. Process variability and waste in business processes are reduced by using a well-structured methodology. (Ferreira, Silva, Mesquita 2013, 1461.)

In other words, Lean Six Sigma is a quality and process improvement strategy, which is aimed to reduce the number of errors or defects in the processes and come close to zero defects. Lean Six Sigma comprises five phases: Define, Measure, Analyze, Improve, Control, and therefore is also called DMAIC methodology.

The use of powerful statistical tools to measure the number of defects in the process is characteristic of the DMAIC methodology. (Sahin 2008, 49; Vivekananthamoorthy, Sankar 2011, 2.)

The DMAIC process is represented in Figure 17.

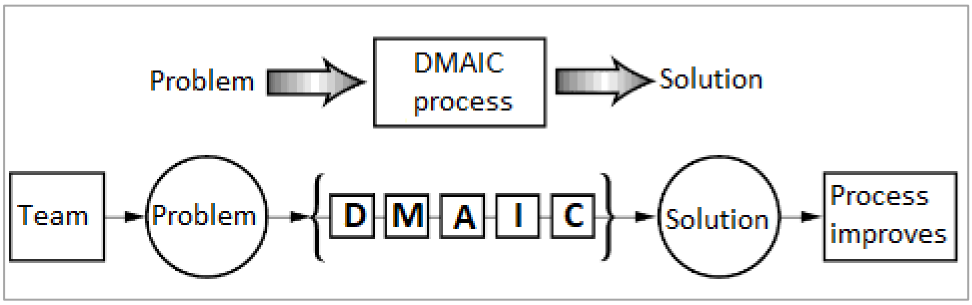


Figure 17. DMAIC process (adapted from Shankar 2009, 52)

3 Research methodology

3.1 Research design and approach

Research design

Research design is a plan that is established to combine the various components of a study in a logical and understandable way. The research method is the strategy used to implement this plan.

Before starting any project, a research plan should be drawn up to decide how to obtain data with the aim of getting answers to the research questions and achieving assigned goals.

Research approach

Triangulation refers to the use of multiple data sources or methods in qualitative research to develop a comprehensive understanding of phenomena (Patton, 1999). Denzin (1989) stated that using several external methods of gathering data related to the same events is crucial to the triangulation approach. He noticed that this approach includes first analyzation of the collected data, and then the presentation of the results in order to understand the experience of the global phenomenon. Denzin (1989) defined the following types of triangulation approach:

1. Investigator triangulation is utilised to weigh the findings of several researchers in a study.
2. Data triangulation is used for correlating people, time, and space.

3. Theory triangulation is applied to compare multiple theoretical strategies.
4. Methodological triangulation correlates data from several data collection methods.

(Fusch, P., Fusch G. E., Ness 2018, 19-22.)

After careful consideration of the theory related to the research process, and comparing it with the stated objectives, methodological triangulation with participant observations, in-depth interviews and content analysis was selected. Cross-functional flowcharts were chosen to define internal processes. It was decided to apply Fishbone diagram, Five Why analysis, SWOT analysis and Drill down pie chart for data analysis. It was agreed to conduct the whole study within the framework of the Lean Six Sigma methodology since it allows to divide the research from the very beginning to the end into thoughtful and understandable steps, which are easy to follow. A closer look at the research process is taken in chapter 6. Research and analysis.

Research plan of this thesis work is shown in Figure 18.

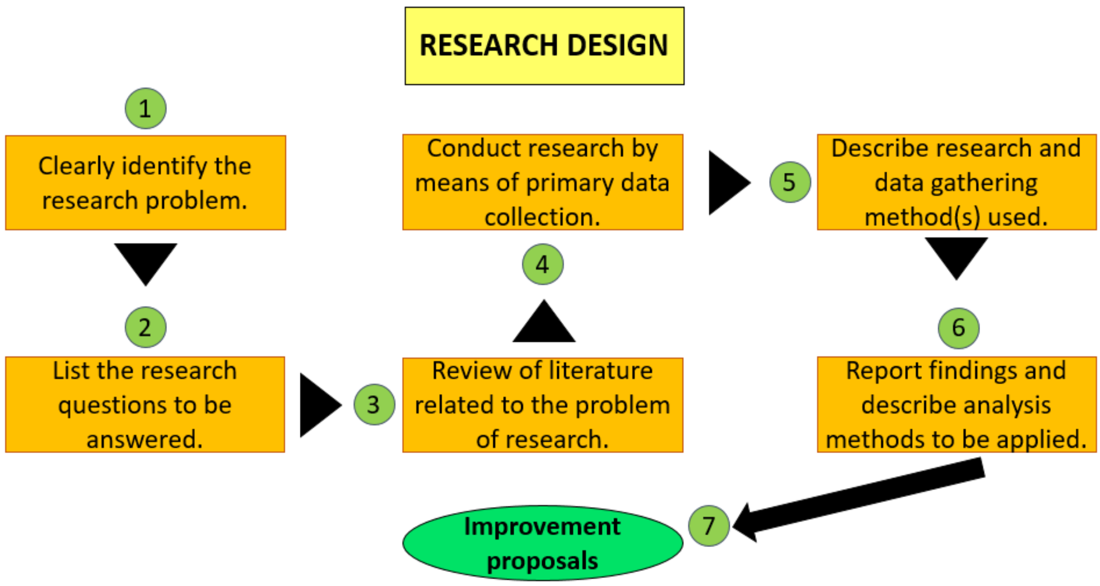


Figure 18. The research design of the study

3.2 Benchmarking

In order to make sure that the research topic of this thesis work is relevant and can bring to better results, benchmarking was conducted.

According to Scott, Edith Cowan University (2011) defines benchmarking as a systematical and ongoing activity of comparing of processes, products and results in other companies with the goal of improving results through the best approaches to practice. In other words, benchmarking is a tool that drives to excellent performance.

Benchmarking was constricted to the time period from 2016 till 2018. It was decided to take into account theses performed for Finnish universities on the subject of logistics.

Throughout the comparative analysis, it was found out that the introduction of ERP systems in warehouses significantly improves productivity. Students have noticed that the use of labeling systems and tag reading devices permits to access information about a certain item at any time. In addition, in one of the researched works it was proved that implemented ERP systems reduce labor costs since most of the operations are carried out electronically. However, software introduction requires a large investment in development and a long waiting time. Likewise, warehouse layout and width of aisles directly affects the speed of the picking process and the overall warehouse efficiency.

Based on the benchmarking, it was revealed that the chosen topic is opportune, worth studying and can lead to satisfactory solutions.

4 Warehouses

Warehouses represent various types of storage, mainly because of the diversity of products or materials that are kept there in different forms. While constructing a warehouse facility, the Building Regulations that set standards for fire resistance and compartment size must be followed. The storage area for hazardous substances ought to be built from non-combustible materials. Floors in warehouses have to be impermeable and resistant to the effects of liquids containing hazardous substances. (Lees 1996, 71-72.)

In other words, a warehouse is a facility for storing goods before they are loaded and transported to the customers.

4.1 Key warehouse processes

Receiving

Receiving is the act of processing goods in a warehouse. Receiving zone is the most active area, and hence, a bottleneck there can affect the entire process. Transporters should use a standard turn to enter the loading dock in order to lower congestion. However, even if it takes a long time, receivers can clear the receiving zone before the arrival of another carrier.

In the receiving area there are personnel responsible for the following actions:

1. Verification of all goods received from the suppliers
2. Inspection of packaging in order to detect visual defects
3. In case of visible defects, an inspection of the contents of the packages
4. Transportation of all checked articles to the put away zone
5. Report of goods with damages in the receiving document

(Faizal 2018.)

Put away

Put away is a process of receiving products from the loading dock, collection area or production zone and delivering them to the final position of the warehouse for keeping. The basic principle is that every time after the inventory is placed in the storage, it is being put away. (Faizal 2018.)

Material handling

Material handling equipment is employed to protect, move and store goods during the entire process of production, distribution, disposal. Large material handling equipment includes trucks, lifts and cranes. Storage bins and cardboard boxes belong to small equipment. Industrial trucks, lifts and conveyor belts are related to transportation equipment. Pallets, wrapping, straps, baskets and racks are types of loading equipment. (Kennedy 2017.)

Picking

Picking involves a gathering of articles in a certain quantity before shipping to the customer. In order to reduce travel time and increase warehouse efficiency, orders can be combined during collection. (Faizal 2018.)

Packing

There are a lot of ways how articles can be packaged. However, ongoing packaging requirements exist and must be fulfilled. Goods have to be packed in accordance with quantity, size, value, fragility, toxicity and temperature. (Walker 2018.)

Dispatching

The main target of successful dispatching is the ability to prepare items for departure on time. Products that are ready before carriers arrive for loading lead to congestions in the staging areas. Therefore, packing and dispatching should be balanced and forecasted due to carrier pick-up times. (Walker 2018.)

4.2 Most common types of warehouse storage systems

There is a number of ways of stacking pallets in a warehouse, and every entity makes a decision according to its stock. Selecting the right warehouse storage system or combination of systems drives to better use of space and increased business efficiency.

Automated storage system

Automated storage systems permit to store and retrieve goods using a computer controlled mechanical arm device. These systems are suitable for searching for small articles (see Figure 19). In addition, if an archive repository has a lot of documents, this structure is applicable and will be also beneficial. Nevertheless, in case of potential technical failure, access to the goods will be blocked. (Pallet racking systems 2019.)

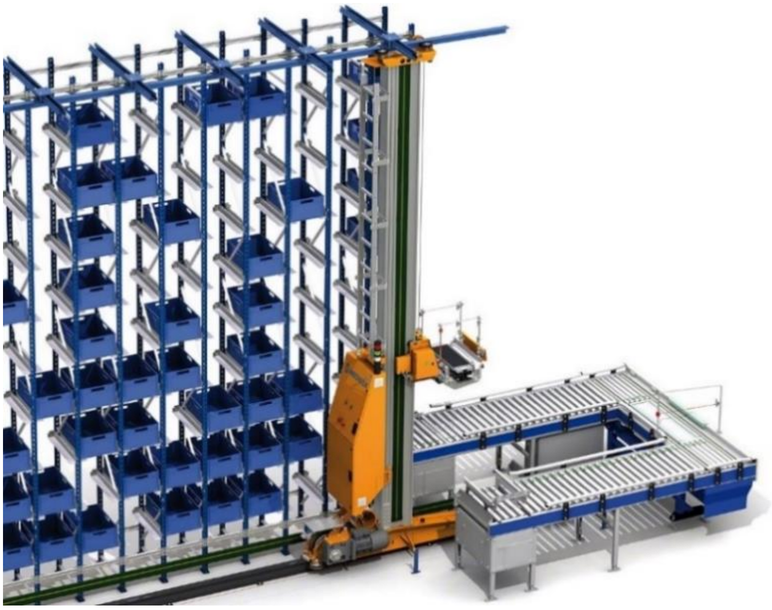


Figure 19. Automated storage system example (retrieved from Mini-Load systems 2019)

Pallet racking

Pallet racking systems are efficient and relatively cheap compared to other existing options. Storing multiple pallets in a framework allows accessing any specific pallet at any desired time. With this system, pallets can be stacked as high as safe, since racks are designed to be stable. (Pallet racking systems 2019.)

Figure 20 demonstrates pallet racking storage system.

Figure 20. Pallet racking system example (retrieved from Pallet Racking Frames 2019)

Block stacking

Block stacking is the most popular storage form, as it does not require any investments and can be applied in any open space of the warehouse (see Figure 21). The key principle of this system is to stack pallets on top of each other in blocks or lanes. However, when goods are extracted, this may lead to insufficient storage capacity. In addition, it is time consuming to retrieve articles from the bottom of a pile. (Pallet racking systems 2019.)

Figure 21. Block stacking system example (retrieved from Lagerung 2019)

Pallet flow

Pallet flow operates on a conveyor belt system, the main benefit of which is automatic movement. After emptying the first container, the next one automatically moves along the conveyor. The conveyor belt system is also suitable for movement of heavy articles, and hence, forklifts will not be needed. However, products in the middle of the system are quite difficult to be reached. (Pallet racking systems 2019.)

Pallet flow storage system is displayed in Figure 22.

Figure 22. Pallet flow system example (retrieved from Pallet Flow Racks and Gravity Flow Storage Systems 2019)

Push back storage

Push back storage system operates like a vending machine and is utilised with pallet racks. Figure 23 represents the basic concept of this system: after the first product has been taken, the next one moves to the front. This storage system is appropriate for products that are loaded and unloaded at the same time, otherwise it will be hard to access goods from the middle of the system. (Pallet racking systems 2019.)

Figure 23. Push back system example (adapted from Pallet Shuttle 2019)

Mezzanine

Mezzanine is an additional storage floor in the existing structure that contributes to the employment of unused vertical space in a warehouse (see Figure 24). If there is enough space in a facility, a mezzanine can double the storage space. (Pallet racking systems 2019.)

Figure 24. Mezzanine system example (retrieved from Long Span Mezzanine Platform 2019)

Drive in racking

Drive in racking storage system is shown in Figure 25. This stricture is applicable for first in and last out products, and therefore it is a good solution for companies with a large quantity of identical cargo. At the same time, limited space affects forklift operations and can increase the time required for loading and unloading goods. (Pallet racking systems 2019.)

Figure 25. Drive in rack system example (retrieved from Drive-in pallet racking 2019)

4.3 Inventory management

According to Saxena (2009, 2), inventory management refers to a process of managing stocks of raw materials, semi-finished goods and finished goods conducted by the company.

Inventory management is a significant function of any organization that influence the supply chain efficiency and impacts the financial balance. The inventory itself represents a stock of goods that contain an economic value, and are used for future production or sales. The next points were highlighted in relation to inventory:

1. All organizations engaged in the production or sale of goods, hold an inventory in one form or another.
2. Inventory is carried out to facilitate future consumption, sale or further processing of goods.

3. The inventory of a firm is considered as an organization’s assets.

(Reman 2019.)

Among the inventory measures one can find the following:

1. Production planning
2. Material requirements planning
3. Sales and operation planning
4. Sales forecasting

(Saxena 2009, 6).

4.3.1 Types of inventory

Direct inventory

Direct inventory is related to the number of materials owned by the organization and implies utilization of all physical components directly for manufacture. Direct inventory is divided into the following groups:

1. **Raw material** inventory includes goods that are going to be used in the manufacturing of end-products.
2. **Work in process** (WIP) is an inventory that contains material for sub assembly stages of the production process.
3. **Finished goods** refer to an inventory that consists of ready-made products that are awaiting sale.

Most of the excising inventories fall into one of the categories above. For example, distribution enterprises transport mainly finished products, while manufacturing firms use mostly work in progress and raw materials. (Muller 2003, 19-20.)

Indirect inventory

Indirect inventory contains items that are used in production, but they are not part of finished goods. Indirect inventories can be classified into the next groups:

1. **Cycle stock** is an inventory, the main purpose of which is to meet the normal demand throughout a given period of time between replenishments.

2. **Buffer (safety) stock** is a stock required to protect an organisation against supply and demand uncertainty.
3. **Speculative stock** is held in order to get quantity discounts, achieve a shortage of materials, and to increase forecasted purchase price in addition to meeting current demand.
4. **Seasonal stock** is a type of speculative inventory, which includes accumulation of stock before a certain season.
5. **In-transit inventory** contains articles that are on their way from one facility to another. Despite the fact, that these items are not available for sale, they can be attributed to a cycle stock.
6. **Dead stock** is an inventory that consists of obsolete products with no demand for a certain period of time.

(Kiisler 2014, 12.)

4.3.2 Inventory valuation methods

First-in, First-out (FIFO) is an inventory valuation method closely related to the actual physical flow of articles, where first purchased goods are used or sold at first. This method is used when the product cost is stable.

Last-in, First-out (LIFO) refers to priority usage or sale of products that have been recently acquired. Companies such as car dealers and retailers who own their own large stocks use the LIFO method. (Kenton 2018; Muller 2003, 20-21.)

Figure 26 represents both FIFO and LIFO inventory valuation methods.

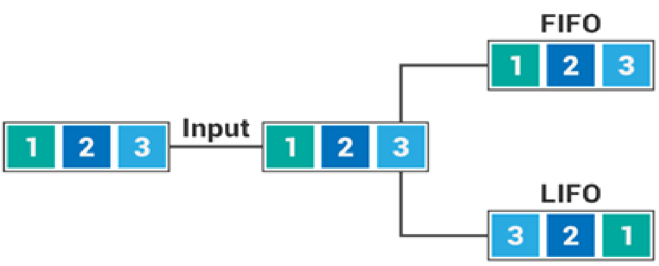


Figure 26. FIFO & LIFO valuation method (retrieved from FIFO, LIFO, and Average Cost Method of Accounting for Inventory 2019)

Average cost method implies that the final inventory includes all products that are available for sale (see Figure 27). This method determines the value of inventory and the cost of articles sold by calculating an average price per unit for all goods accessible for selling over a specific period of time. This valuation technique is utilized when the cost of the product is unstable. (Kenton 2018; Muller 2003, 20-21.)

Figure 27. Average cost valuation method (adapted from Accounting standard 2, Inventory valuation Complete Guide 2019)

Specific cost valuation is a method by which a company can monitor the actual item cost inside, outside and through the organization. This valuation technique is mainly applied by companies with complex computer systems or when an organization deals with expensive items, such as pieces of art. (Kenton 2018; Muller 2003, 20-21.)

Specific cost valuation method is illustrated in Figure 28.

Figure 28. Specific cost valuation method (adapted from Accounting standard 2, Inventory valuation Complete Guide 2019)

Standard cost method is used in manufacturing companies in order to provide the equal cost of items for all internal departments within one year (see Figure 29). This technique should be selected when controlling the cost is critical. (Kenton 2018; Muller 2003, 20-21.)

Figure 29. Standard cost valuation method (adapted from Accounting standard 2, Inventory valuation Complete Guide 2019)

4.3.3 Inventory management concepts

Just in time (JIT) inventory management

According to Kootanaee (2013, 8), Fiedler, Galletly and Bicheno (1993) defined Just-in-time (JIT) manufacturing as Japanese management philosophy applied in production, the fundamental principle of which is the availability of the right products of the right quantity and quality in the right place “just in time”.

Proper implementation of JIT concept leads to an increase in productivity, quality and efficiency and decrease in costs and unnecessary movement of labour, equipment and materials. Suppliers deliver their goods at the right time, and thereby, customers also receive their orders at the right time. (Mand 2013, 86-87.)

Among other feasible benefits of JIT is a reduction of total inventory level, and therefore a decrease of investments in inventories. Furthermore, due to shorter delivery times, the reliability of order fulfilment increases, and this contributes to a reduction in the safety stock requirements. Shortened total lead time, which includes production and purchasing lead times, brings to the elimination of firm’s scheduling in production planning framework. (Kootanaee 2013, 14.)

Lean inventory management

According to Yam (2009, 887), the primary idea of lean management is to reduce resource consumption, which does not add value to ready-made goods. The main attention is drawn to waste from labour and materials from all areas of manufacturing and inventory.

As a result of implementing lean manufacturing, all processes run faster and become less costly. Improving product quality to zero defects, fast cycle times, inventory reduction and small batch sizes are also characteristic of lean manufacturing. (Taghizadegan 2006, 61-62.)

5 Warehouse improvement methods

Efficient performance of a warehouse along with saving money and time is a key factor leading to the success of any distribution company. Since all internal components of the warehouse are bound, they should work as a coordinated mechanism to ensure great outcomes in the future. Thus, good warehouse managers are constantly trying to find ways to improve operational efficiency.

5.1 Warehouse layout and design

Data collection is the basic component of the design or redesign of the warehouse. Information such as number of SKUs, throughput monthly, annually and seasonally, characteristics of order, receiving, shipping and storage have to be available in the company. (Freese 2000, 1-3.)

Design of a warehouse includes three steps: pre-engineering, engineering and implementation.

1. Pre-engineering

The key task of the pre-engineering phase is to denote a management strategy used. The strategic purpose of the warehouse should be also decided.

Conceptual design

Conceptual design provides gross calculations that help to determine the size of the warehouse and costs required for its construction.

Layout planning

Layout planning includes defining the amount of manpower needed for the facility, which depends, for example, on how far the storage and receiving zones are located from each other. Likewise, evaluation of the alternatives should be made in the warehouse. By alternatives, forklifts, pallet jacks are understood. At this stage, general requirements for information and management systems can also be developed. (ibid., 4.)

Trade-off principles

In order to choose the most suitable alternatives for a warehouse, some general trade-off principles such as stock groupings, the shortest travel distance, longer run times, floor space measurements and balancing activities have to be considered. (ibid., 5.)

2. Engineering

Engineering phase implies the development of an engineering layout drawing of the warehouse. This drawing shows the location of the aisles, racks and amount of space required for each rack. In addition, columns that support the facility should be taken into account in the drawing. At this phase, lighting, electrical drawings are also created. (ibid., 5-6.)

Figure 30 presents possible storage configurations in accordance with ABC analysis.

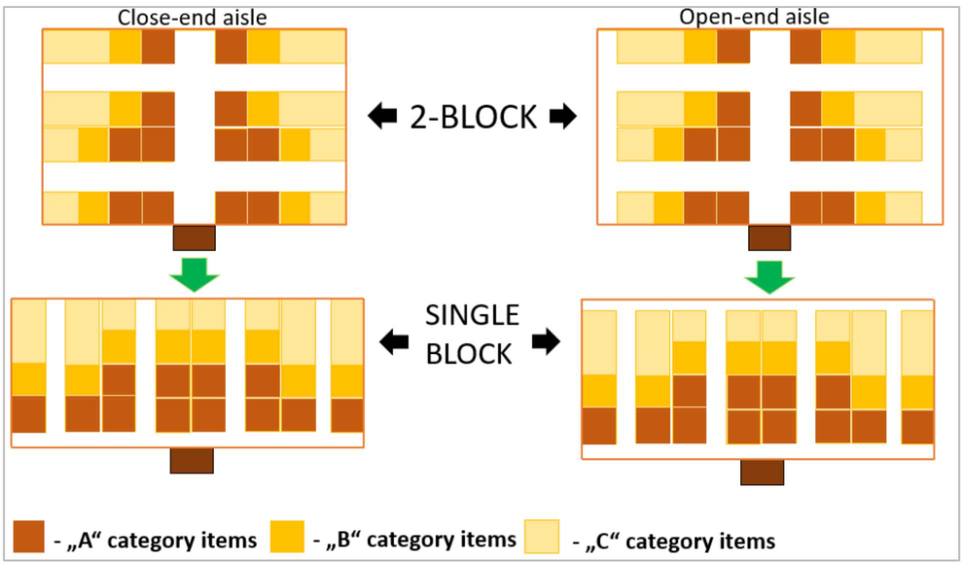


Figure 30. Layout configurations (adapted from Koster, Delfmann 2005, 201)

3. Implementation

A good warehouse should support the strategic plan of an organisation, customer service goals, and lower target.

Possible reasons leading to the need for a redesign of a warehouse are:

1. Increase of delivery errors
2. Decrease of availability of storage space
3. Increase of cycle time of an order
4. Growth of congestions
5. Need of more space outside and inside the facilities
6. Growth of problems with inventory control and management

(ibid., 6.)

5.2 Warehouse management system

Warehouse management system (WMS) is considered as the main part of the supply chain process and is aimed to monitor the storage and movement of goods in the warehouse. The primary goal of WMS is to control receiving and returning of articles, manage inventory and connect logistics with order processing. This software can also optimize put away process using real time information.

Automatic identification and data capture (AIDC) is frequently applied in the WMS system in order to control the flow of products. By AIDC such technologies as radio-frequency identification (RFID), barcode scanners, mobile computers, magnetic stripes, wireless local area networks (WLANs), smart cards and biometrics are meant. AIDC is the process of collecting external data by converting an actual image or a sound into a digital file. This file can be analyzed and, if needed, compared with other existing files in the database. Likewise, AIDC is utilized in the processes of recognizing objects and obtaining the necessary information about them. After data is gathered, information is sent to a central database, where all the required information about products in the warehouse is stored. (Warehouse Inventory management 2019.)

Among potential advantages of installing WMS one can discover the following:

1. Accurate stock
2. Stock visibility and traceability
3. Error reduction
4. Fewer returns of goods
5. Less paper work
6. Accurate reporting
7. Better customer service
8. Remote data visibility

(Gwynne 2011, 138-139).

5.3 Warehouse labels and identification

Storage labeling is the main element of warehouse design. Warehouses where it was decided to abandon the installation of labeling, face with the lost inventory or wasted labor hours. (Supply Chain & Logistics Basics 2019.)

Barcode labels facilitate inventory tracking and access to data regarding articles (Fabregas 2018).

There is a number of barcode types, and some of them are described in Table 2.

Table 2. Barcode types (adapted from Barcode labels 2019)

Code	**Description**
Code 39 12345678	Code 39 is one of the oldest barcodes found in electronics, healthcare and government. It is lineal, discrete and self-checking code.
Code 128 12345678	Code 128 is one of the most popular, high density linear barcodes. It is applied to encode a large amount of data in a small space.

Universal Product Code (UPC) 1 23456 78125 2	UPC can be found on almost every retail product to ensure fast receipt printing and inventory tracking.
Quick Response (QR) Code 12345678	QR code is gaining popularity as a marketing tool for linking to web information.

Label types

Types of warehouse labels include the next:

1. **Rack labels** – labels that are used to identify the location of the pallet in racking systems.
2. **Retro reflective pallet rack labels** are marks on high level rack beams that can be scanned from the floor.
3. **Floor labels** – tags used for identification of floor storage location.
4. **Shelf labeling** is a system that is applied for slot and stock keeping unit (SKU) locations.
5. **Metal tags** are considered as the most durable barcode labels.
6. **Freezer labels** are applied in cold stores and can be used at -29 °C.

(Warehouse Labels & Identification 2019.)

Introduction of a suitable labeling system leads to effective inventory management and simplifies the process of selecting items in the warehouse. Labeling system saves time for workers to find the right location in the stock and ensures the safety of employees and goods. (How Mobile Printing Benefits Warehouse Operations 2013, 2.)

Labeling technology

The RFID technology is employed to read coded digital data using radio frequency waves. To support efficiency and accuracy at a sufficient level in the stock, RFID systems are required.

Mobile barcode printers produce and attach RFID labels and barcodes when they are applied. Implementation of mobile barcode printers can lead to optimization of marking operations in difficult accessible locations, reduction of operator errors and elimination of costs by correcting errors. (How Mobile Printing Benefits Warehouse Operations 2013, 2.)

Label readers

Barcode readers are used to scan barcodes, converting code into numbers that are transmitted to a computer. Product and company information appears in the software and can be reached at any time.

There are many types of barcode readers: starting with the simplest and least expensive types – wand readers and ending with laser scanners, which, respectively, are considered the most expensive and modern ones. Charge-Couple-Device (CCD) that is used to check counters, slot scanner that is applied to scan ID cards and image scanner with an integrated small camera can be found among others readers.

Barcode readers can be joined to a computer via a wireless connection, a universal serial bus (USB) port or a serial port. (Andrews 2009, 370-371.)

5.4 ABC Analysis

Activity-based costing (ABC) is defined as a methodology, the main task of which is to determine the cost and efficiency of resources, cost objects and actions performed. Recourses are assigned to operations, and operations, in turn, are assigned to cost objects depending on their use. ABC recognizes a causal relationship of factors affecting value and activity. (Institute of Management Accountants 1998.)

ABC analysis is a popular technique that brings to good inventory management and is used for stock classification in the warehouse. Pareto Principle, which states that about 20% of the total amount of goods makes up to 80% of the total consumption value, underlies ABC analysis. As a result, inventory is divided into three categories based on the consumption of units per year, stock value and costs. Categories are respectively as follows: A, B and C. A-items refer to high value goods with 80% of the annual consumption of the company, which is 10-15% of the total inventory. B-items are products of average cost with a medium consumption value of 20-25% annually, which is 15% of the total number of items. C-items are small value items with 5% of annual consumption for 60-70% of total inventory items. (10 Ways to Improve Your Warehouse Inventory Management 2017.)

Figure 31 displays an ABC analysis example.

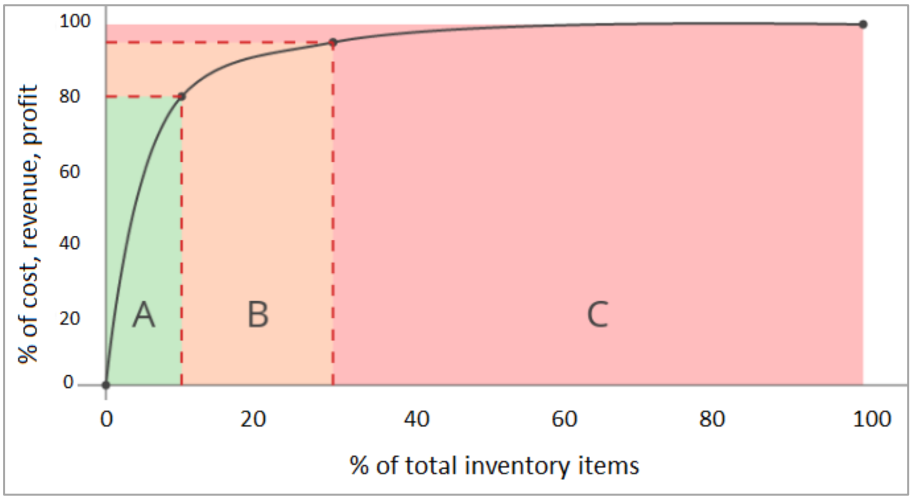


Figure 31. ABC analysis example (retrieved from ABC analysis –The Ultimate Guide to Inventory Classification 2017)

To the advantages of ABC analysis, the following points can be attributed:

1. Increase of efficiency

ABC analysis contributes to the strict control of the most valuable items. Therefore, articles from “A” category are monitored thoroughly and protected from possible damage or theft. The company controls the demand and level of use to order a sufficient quantity of certain items and avoid excess inventory that may become obsolete. B-items receive standard control, such as periodic reviews and prediction of random use. Items from category “C” get minimal control.

2. Investment reduction

This analysis leads to a reduction in investment, since, according to ABC analysis, A-items are acquired in smaller quantities as far as possible.

3. Reduction of storage cost

Considering that goods from category “A” are purchased in smaller quantities, it drives to the minimization of storage cost.

4. Strategic Pricing

ABC analysis impacts on the strategic pricing of products that benefit the firm. By tracking goods, an organisation can raise the price of the most demanded items, which will increase profits. (6 Basic Benefits to Adapting ABC Analysis of Inventory 2017; Merritt 2019; Shah 2019.)

5.5 Cross docking

Cross docks are high speed warehouses that contribute to the reduction of transportation costs. Product is moved directly from receiving to the shipping area, bypassing the storage and retrieval steps. The main characteristic of a cross dock is existing of little or no storage. Nevertheless, material handling equipment is used there. Such equipment as pallet jacks and forklifts can be applied.

Articles are sorted at cross-docks for individual stores and combined with products from other suppliers, which leads to a full load of trucks and, consequently, significant savings. (Bartholdi, Hackman 2011, 213-215.)

Figure 32 illustrates a typical cross docking terminal. Small orange rectangles around the large one depict trucks arriving for unloading, while green ones represent trucks ready for loading. Large white rectangular shows the terminal itself.

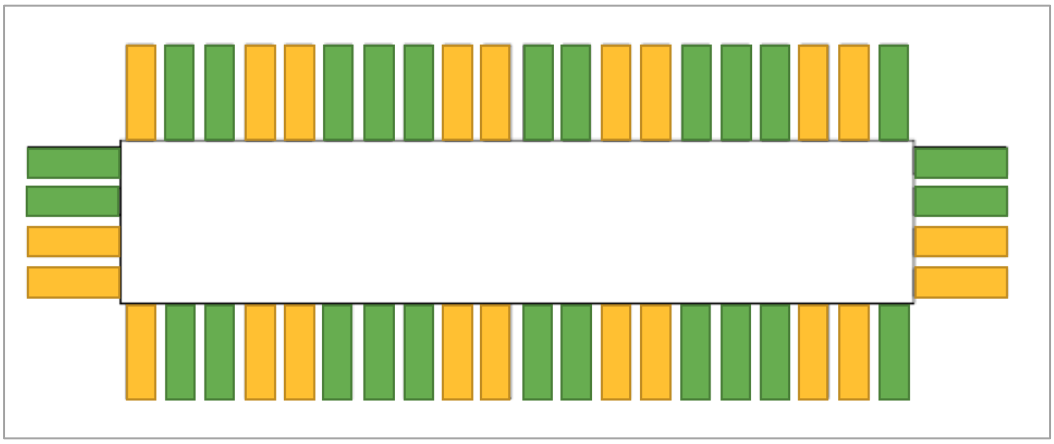


Figure 32. Typical crossdocking terminal (adapted from Bartholdi, Hackman 2011, 214)

5.6 ISO 9000 Quality Management system

The ISO 9000 standards were developed to support organizations in the implementation and operation of effective quality management systems. For an organization to be successful, it is significant to control it systematically. Implementation of a management system that is aimed to refine productivity while meeting the needs of all stakeholders can bring to a company´s success.

Quality management principles were defined as follows:

1. Leadership
2. Customer focus
3. Process approach
4. System approach to management
5. Involvement of people
6. Continual improvement
7. Mutually beneficial supplier relationships
8. Factual approach to decision making

(International Standard 2005, 5.)

ISO 9000 can be of the next types:

1. **ISO 9001** quality standard is a standard that specifies requirements for a quality management system, in which a company ought to confirm its ability to provide products that meet customer requirements and ensure customer satisfaction.
2. **ISO 9004** quality standard insures guidelines that take into account both efficiency and effectiveness and of the quality management system. The purpose of this standard is to increase the efficiency of the institution and satisfaction of customers and other parties concerned.
3. **ISO 19011** is management system auditing standard. The main goal is to improve processes and practices and to strengthen the effectiveness of an existing program.

(ibid., 6., ISO 19011, 2011.)

6 ERP system in warehouse

6.1 Background of ERP

Enterprise Resource Planning (ERP) is a system that combines manufacturing, financial and human resources into one computer program (Schoenfeldt 2008, 183).

ERP systems were launched in the 1970s. The history of ERP systems is related to Materials Requirements Planning (MRP), which was designed by Joseph Orlicky in 1964. MRP was created in order to control inventory and plan production. Later, in 1983 Oliver Wight enlarged MRP into MRP II. Sales and operations planning (SOP), master scheduling, capacity requirements planning (CRP) were added into the MRP II. MRP and MRP II were software systems.

Among standard characteristics of ERP system there are:

1. Using one common database and automatically linking all business processes
2. Keeping a complete audit trail of all transactions
3. Shortening the time between transactions
4. Improving customer service

5. Using automatic internal conversions such as foreign currency, taxes or product pricing

(Tetteh, Uzochukwu 2015, 28-29.)

6.2 Benefits and challenges

Some of the upsides of the introduction of ERP include the following:

1. **Enhance organizational performance** is the main goal of many ERP systems.
2. After the implementation of an ERP system, **understanding of business operations** is developed by tracking information in the process.
3. **Fully integrated business functions** maintain business processes. Real time information contributes to improving customer service, reduction of costs and time.
4. ERP enables to **link directly other systems**, both externally and internally. These systems include other ERP and software systems, such as product lifecycle management (PLM) and customer relationship management (CRM).

(Tetteh, Uzochukwu 2015, 32-33.)

However, the realization of ERP has its challenges, and they are as follows:

1. Implementation of ERP can **cost** large enterprises **hundreds of millions of dollars**. These costs include software itself, implementation team, training of labor and other related expenses.
2. Companies may **encounter difficulties** while using ERP system after its realization.
3. A new information system in most cases **affects the quality of work** within the organization. Its implementation can cause changes in the company culture.
4. ERP **can be** very **disruptive** for the business processes within the organization because people do not want to switch to a new system. People can sabotage the new system in the worst case.

(ibid., 33-34.)

7 Research and analysis

In order to find and present results, the Lean Six Sigma method was applied in this thesis work. Each phase is presented separately for transparency of the study, and every next step follows the previous one, which makes research logical, consistent and easy to follow.

7.1 Define Phase

The Define phase is the first phase of the Six Sigma improvement methodology. It facilitates to define the main goal and internal processes in the case company.

7.1.1 Defining the fundamental goal

Research in FRIES was carried out using content analysis. From the 5th of January till 5th of February 2019, the primary task was to study internal processes of FRIES, such as production, packaging and warehousing within the entire organization. Furthermore, order and shipping documentation has to be learned, as well as how to prepare goods for shipment.

In short, awareness of the whole process in FRIES from production to the shipment stage was crucial for the research.

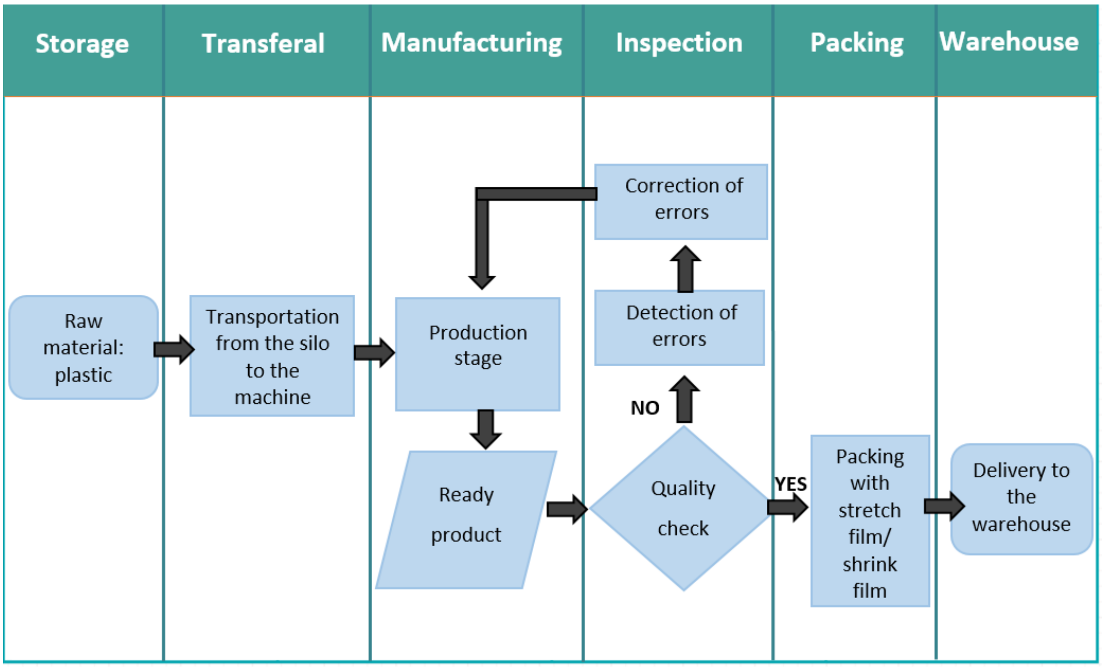
In addition to the content analysis, participant observations were conducted. It was monitored how forklift drivers coped with searching for the required products in the warehouse and how quickly they dealt with this task. Besides, it was checked how fast workers delivered products to the first and second floors, where and how they placed goods in case of lack of space. By dint of observation method, information was obtained from the first hands, and congestion and violations committed while operating were marked. Under violations overload of the elevator, blockage of the passage and fast driving of forklift drivers are meant.

Based on the research accomplished, the key target of the thesis work was identified. The main goal is to optimise the use of warehouse space and its processes and unite optimization solutions with the ERP system in the case company. A closer look at research objectives is taken in sub-chapter 1.5 Research objectives and questions.

7.1.2 Defining internal processes in the case company

In order to show the internal processes within the case company, two cross-functional flow charts were created. The manufacturing flow chart is demonstrated in Table 3 and the retrieval process is presented in Table 4, respectively.

Table 3. Cross-functional manufacturing flow chart

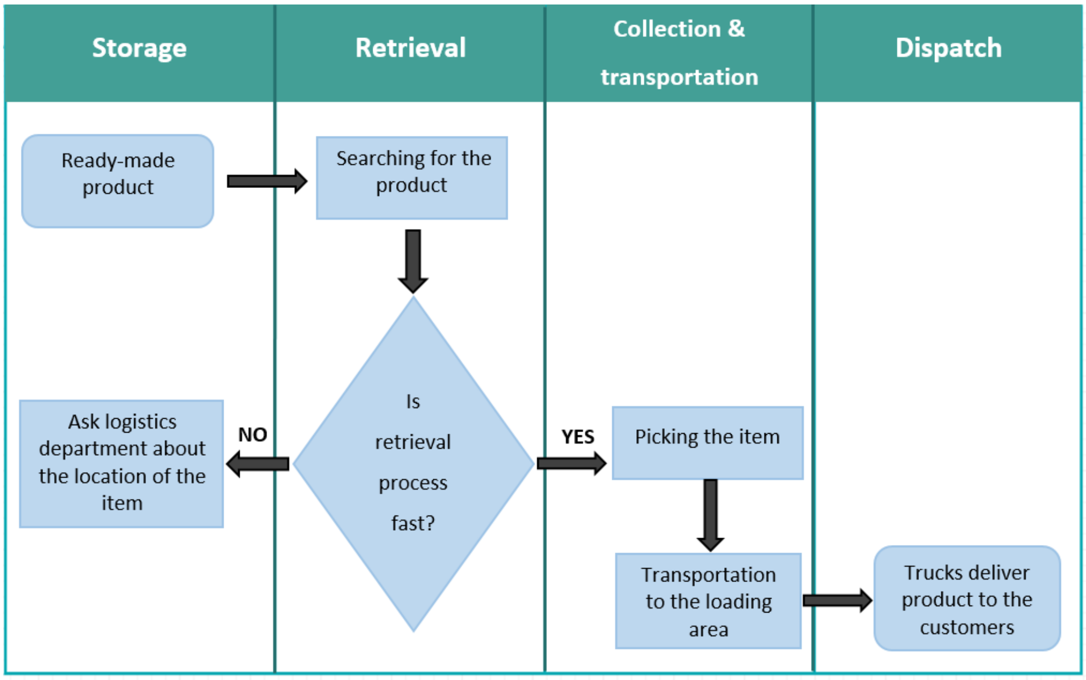


In the case company plastic, as main raw material, is utilised in production. Plastic is transferred directly to the machine from the silos. Silo is a storage tank for bulk materials. If the order requires products of a certain colour, coloured granules are also delivered to the machine and mixed with the plastic from the silos. Next step is the manufacture of the ordered goods.

After goods have been produced, they pass a quality control stage. In case of successful inspection, articles are packaged in stretch film or shrink film, depending on the way of production. Goods made in extrusion moulding area are packaged in stretch film, while products manufactured using injection moulding machines are packed in shrink film. A closer look at the production process is taken in sub-chapter 1.3 Production technologies in Fries Kunststofftechnik GmbH.

Further after packing, items are delivered to their storage places. However, if some errors or failures have been detected, they are corrected before proceeding with production.

Table 4. Cross-functional retrieval process flow chart



Ready-made goods are waiting for shipment in the repository. Warehouse workers should find the required articles before the arrival of the truck. However, retrieval process may be a daunting task. In case of difficulties, workers are supposed to ask logistics department about the location of needed items. Once articles are retrieved, they are collected and transported to the loading area. After loading into trucks, products are supplied to the customers.

7.2 Measure phase

Once the problem was understood, all efforts were directed towards collecting suitable and reliable data in order to narrow the scope of the investigation.

During Measure Phase, data was not only gathered but also structured with an eye to analyse it and afterwards draw conclusions.

In-depth interview method was applied in the data collection stage. In-depth interviews were held in a one-on-one setting because face to face contact was significant for the perception of the emotions and attitudes of the respondents. Moreover, throughout the interviews, it was handy to explain questions that were vague for the respondents, and thus more accurate answers were received.

Since the case company is located in Austria and the national language is German, interviews were carried out in both English and in German. Questions that were asked while the interviews are represented in Appendix 10 and 11.

Ten employees with extensive work experience in FRIES were chosen and interviewed. The key aspects to focus and elucidate during interviews were identified as follows:

1. Evaluation of usage of warehouse space
2. Estimation of time utilisation
3. Distribution of human resources.

Interviews were conducted on the basis of the predetermined aspects that are mentioned above. Throughout the conversations, the most prevalent topics related to the main points were embraced, and each was divided into two groups based on the replies of the respondents. It was decided to document results through creating a structural table for a better understanding and further analysis. Table 5 summarises the findings accumulated.

Table 5. Structured interview results

Discussed issues							
Evaluation of usage of warehouse space				Distribution of human resources		Estimation of time utilisation	
Warehouse space		Availability of free warehouse space		Carting of goods		Tracking of articles	
not fully optimised	optimised	not enough	enough	quite slow	fast enough	necessary	not needed
9/10	1/10	10/10	0/10	8/10	2/10	10/10	0/10

Since the interviews were performed in a one-on-one setting, comments on each of the discussed topics were obtained. Most of the respondents declared that they found out that storage areas are not fully optimised when monitoring how they operate. The lack of warehouse space led to the use of outdoor storage. One of the interviewed considers that the lack of storage capacity can also be recognized at the production planning stage. He clarified that some machines can produce in bigger lot sizes, but sometimes program has to be switched during manufacture. Fairly slow cargo transportation, according to the employees´ opinions, causes congestions. Two of the respondents denoted that a possible reason for the cluster is the absence of a night carrier, so the goods are waiting at the collection point until morning. It turned out that the installation of a tracking system is indispensable, otherwise uncertainty of the products’ locations drives to a long searching time.

7.3 Analyze phase

Solutions cannot be elicited until the disclosure of the veritable root causes of the problems. Hence, Analyze Phase is one of the most meaningful phases before the providing of feasible improvements.

In order to analyze answers captured during interviews, Affinity diagram was used (see Figure 33).

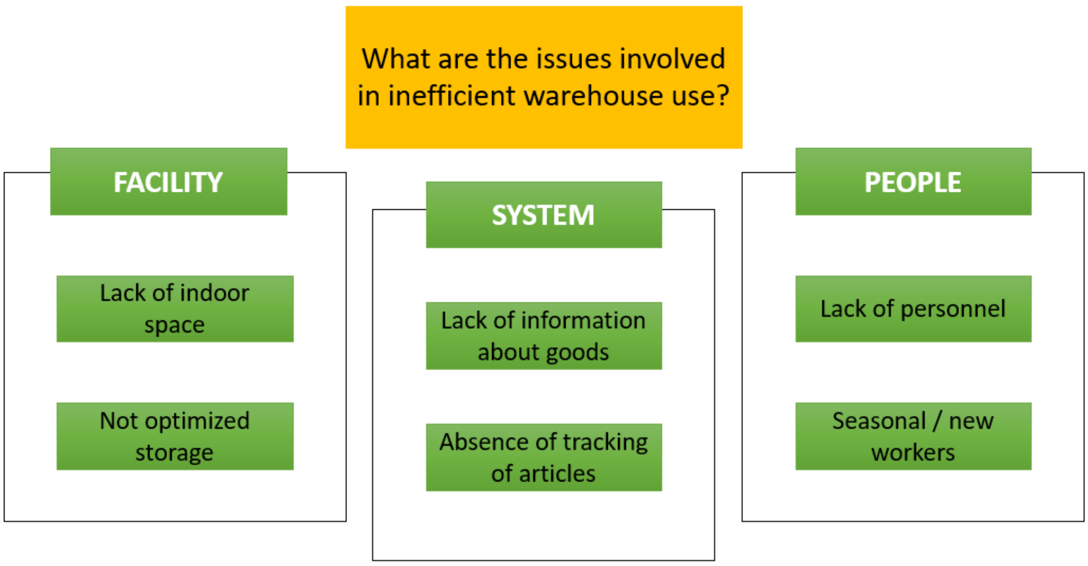


Figure 33. Affinity diagram

Based on the analysis conducted, it was concluded that three components affect inefficient warehouse use. These elements are as follows: warehouse facility, software system and working people. Facility component is directly related to the use of space, while the system and people are associated with the use of time.

7.3.1 Root causes analysis

A Fishbone diagram was created to determine the causes of inefficient use of warehouse space in the case company.

The diagram is displayed in Figure 34.

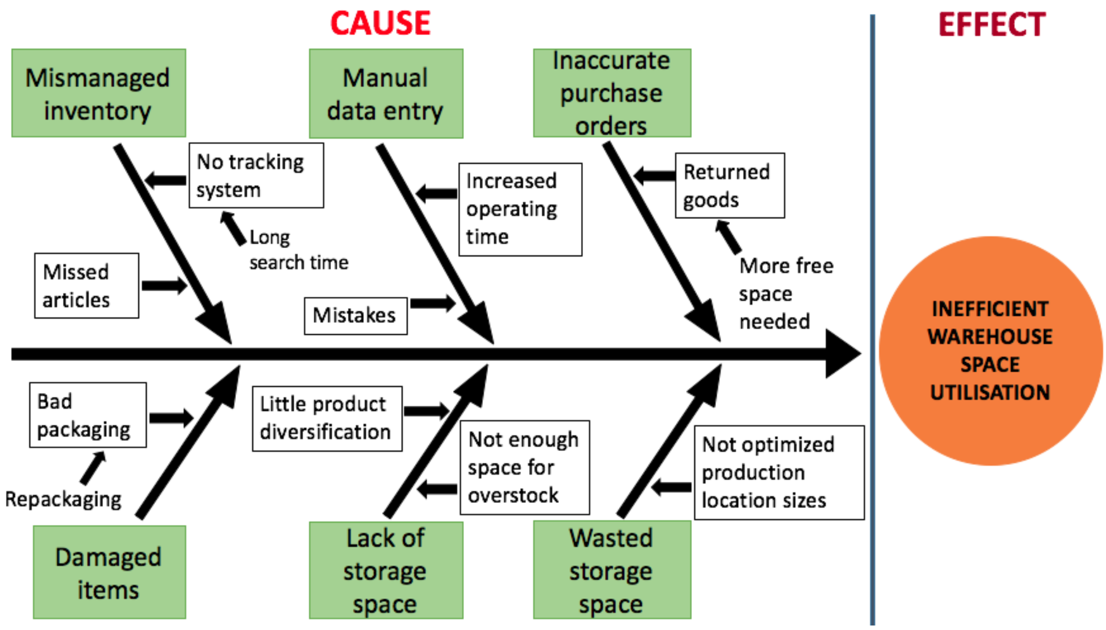


Figure 34. Fishbone diagram

Black horizontal arrow is called the spine of the Fishbone diagram and it is pointed to the main concern: inefficient warehouse space utilisation.

Potential causes of the problem were disposed in the green boxes and directed towards the spine of the diagram with the help of large black arrows. As potential causes, the following points were revealed: mismanaged inventory, manual data entry, inaccurate purchase orders, damaged items, lack of storage space and wasted storage space.

Sub-causes are located in the white boxes with a black outline and marked with small black horizontal arrows next to them. Absence of a tracking system, which leads to a long searching time, and missed articles are characteristic to the mismanaged inventory. Increase of operating time and probable errors are components of the manual data entry. As for inaccurate purchase orders, this leads to the return of goods that require more storage space. Bad or poor packaging is distinctive for the damaged goods and induces repackaging and double expenses. There is a small opportunity for product diversification within the company, and there is not enough space for overstock due to the lack of storage space. Not optimised product location sizes are constituting part of the wasted storage space.

With the help of Five Why analysis, the root cause of inefficient utilization of time while operating in the warehouse was defined (see Figure 35).

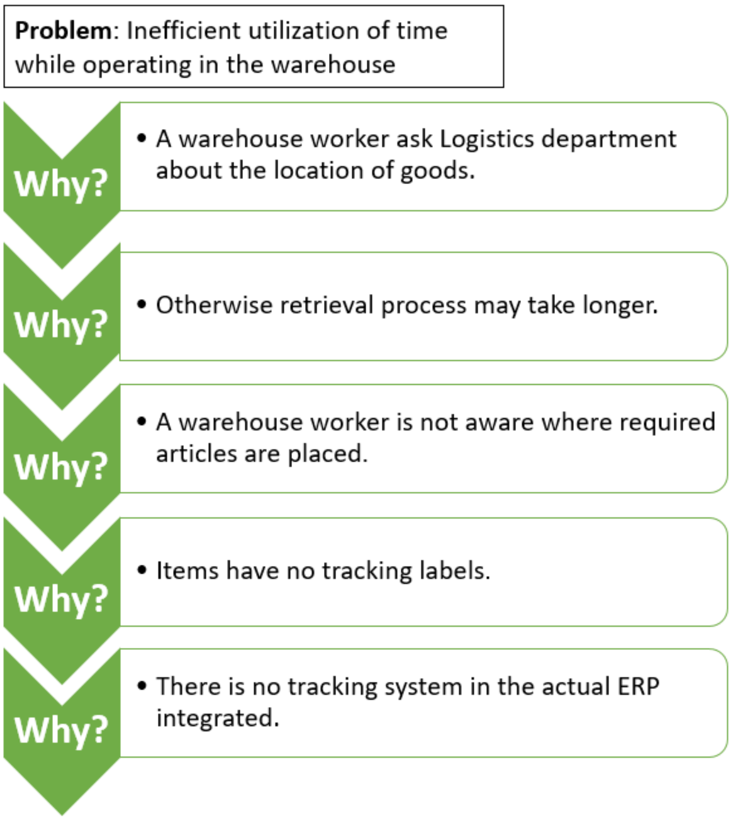


Figure 35. Five Why analysis

The first "Why" question was asked to the stated problem, which is placed in the white rectangular. Next "Why" question was asked to the obtained answer that is located in a box with a green outline below the problem. Regarding the same principle, the root cause of the problem is located in the bottom box with a green outline.

7.3.2 Analysis of secondary causes

Lack of storage areas holds down diversification of the products inside the company, as it was determined using the Fishbone diagram.

Based on the interviews´ outputs, horizontal or concentric diversification can take place in the case company. Horizontal diversification strategy involves the manufacturing of new and unrelated products but targeting existing customer base as potential customers. Concentric diversification occurs when a new product is created using existing technologies and introduced to a new, but related market. (Cole1997, 71.)

A Drill down pie chart was constructed in order to find advantages of potential diversification (see Figure 36).

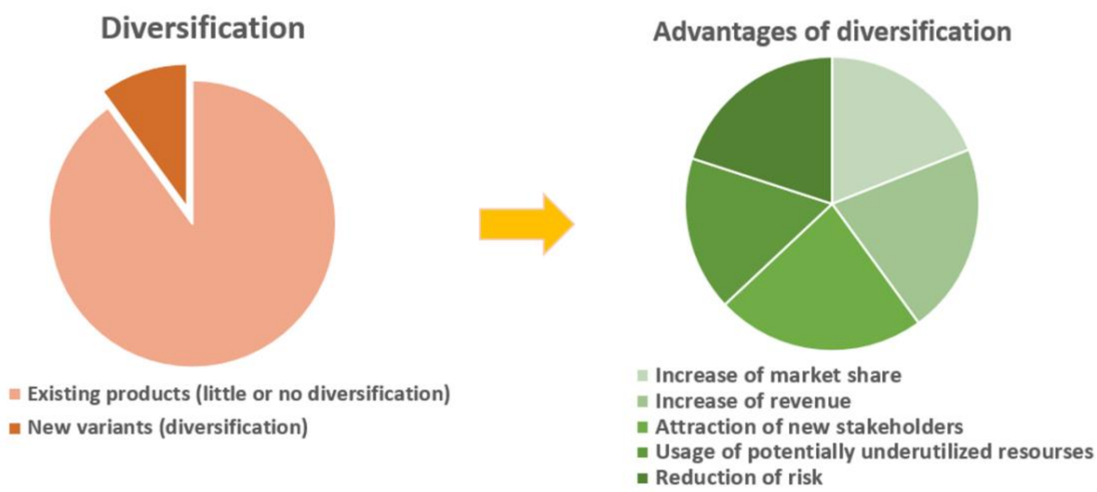


Figure 36. Drill down pie chart

Increase of market share can be detected among the benefits of diversification. Companies attract new customer groups by presenting new products. Furthermore, the previously mentioned strategy can lead to an increase in profits mainly due to attracted customers and potential cooperation with them. From the stakeholders' point of view, an organisation that has implemented diversification is perceived as innovative and ambitious. Hereby, by means of successful diversification new investors can be attracted. Diversification contributes to maximizing the use of potentially underutilized resources. This strategy also assists to reduce risk by entering a new market due to a slowdown in existing sectors.

However, like any strategy, diversification has its downsides apart from already mentioned upsides. It was decided to pay attention to the most possible ones.

On the negative side, the introduction of a new product in a new market may lead to greater competition and potential changes in preferences of current customers. In addition, existing products may be perceived as obsolete because of new ones. Diversification implies high development, marketing and sales costs at the implementation phase. In case if these costs exceed the potential profit, diversification will be a disadvantage. Diversification may sow doubts among current customers that the enterprise is interested in their business to the same extent as earlier. Moreover, unsuccessful diversification can negatively affect the company's reputation and damage relations with investors. (Johnston 2019, Linton 2016.)

7.4 Improve phase

Following up the analysis conducted, it became clear that optimization should be carried out in terms of space and time. By providing solutions, “Blaserei” and “Spritzerei” warehouses were taken into account, as well as the new constructing storage. To prove that the improvements are procurable for the company, calculations are presented.

7.4.1 Optimization in terms of space

In order to optimise space usage, it was agreed to divide the warehouse into zones and mark each with a certain colour. Since the case company has two warehouses based on the production fields, they were considered separately.

“Blaserei” warehouse

At first “Blaserei” warehouse was taken into consideration. There are seven variants of manufactured goods in extrusion blow moulding production. Separation is based on the canisters of the following volumes: 10 litres, 12 litres, 20 litres, 25 litres, 30 litres, 60 litres and drums of 220 litres. Canisters can be of different colours and with different screw caps, and therefore every single type has its own vendor code, but it still should be located in the defined colour zone (see Table 6).

As for drums, they are placed in metal frames and should be temporarily stored in the production zone. Because of metal frames´ dimensions, it is impossible to deliver them into the warehouse. This problem is currently being solved by constructing a new warehouse, where they are going to be kept.

Based on the orders´ frequency, canisters of 30, 20, 60 litres are produced at most. Hence, they are located on the ground floor, and left articles are transported to the ground and mezzanine floors (see Figure 37 and 38). As the mezzanine floor is an additional floor for storage in the existing structure, there is free space under it to keep more articles. FRIES decided to store cups produced by means of injection blow moulding there. In cellar floor, there are goods from both “Blaserei” and “Spritzerei” production fields (see Figure 39).

Table 6. Colour zones in “Blaserei” warehouse

Volume of the product (litres)	Colour of the zone
10	
12	
20	
25	
30	
60	
Cups	
Cups with special print	
Cans	
Inner parts for racks	
Racks	
Lids for buckets	
Buckets	
Carton	
Screw caps	
For others	

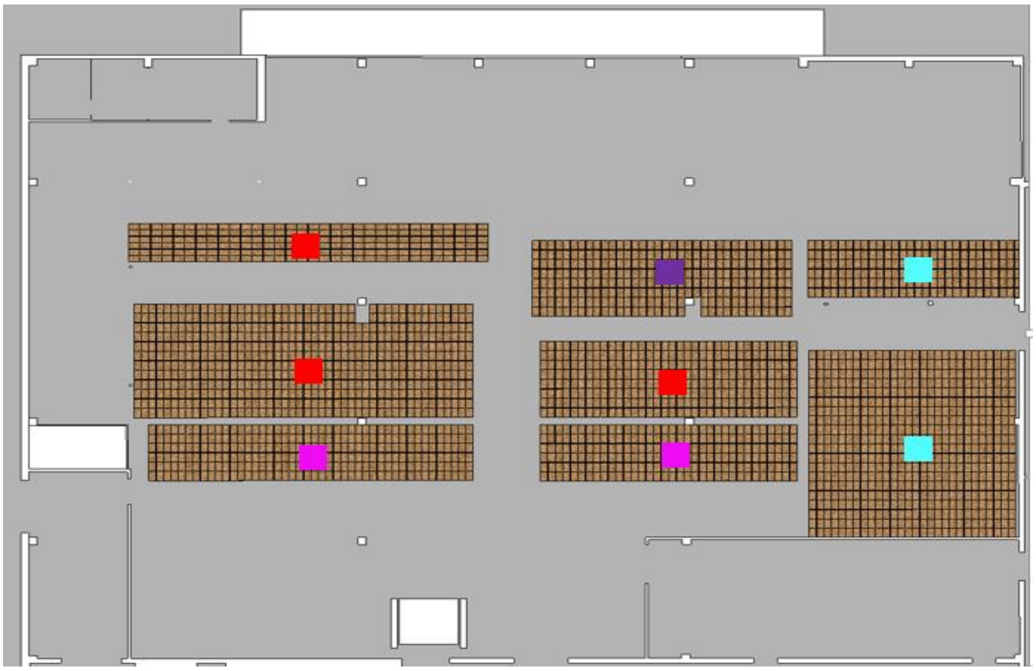


Figure 37. Location of goods based on colour zones in “Blaserei” warehouse (ground floor)

Figure 38. Location of goods based on colour zones in “Blaserei” warehouse (mezzanine floor)

Figure 39. Location of goods based on colour zones in “Blaserei” warehouse (cellar floor)

“Spritzerei” warehouse

It is important to notice that “Spritzerei” produces much more products and their types, and hence, colour zones were divided based on the product names.

By injection moulding, seven types of racks of different sizes are produced: basic, glass, bistro, plate, cup, tray and accessories racks. Inner parts for these racks can be of different sizes and shapes, respectively. Cutlery baskets, cutlery holders and carriers are also manufactured in this production area and may have different colours.

Cans and buckets are produced from various plastic, and depending on the purpose of further use, plastic can be more or less robust. Buckets may have such characteristics as cold resistance or electrical conductivity. They can be designed using screen printing and can be of various sizes, shapes or colours. Lids and handles for cans and buckets are made in different sizes, accordingly.

Industrial baskets category includes workpiece carrier systems, technical and cleaning racks.

Every single type of earlier mentioned products has its own supplier code, but it should still be placed in a specific colour zone based on the product name (see Table 7). Buffer space is interned for storage of goods that will soon be loaded into trucks.

Table 7. Colour zones in “Spritzerei” warehouse

Name of the product	Colour of the zone
Racks	
Inner parts for racks	
Cutlery baskets	
Buckets	
Lids for buckets	
Crokery transport boxes and lids	
Reusable plates	
Industrial baskets	
Cups with print	
Buffer space	

Figure 40, 41 and 42 represent the distribution of products produced in “Spritzerei”.

Figure 40. Location of goods based on colour zones in “Spritzerei” warehouse (ground floor)

Figure 41. Location of goods based on colour zones in “Spritzerei” warehouse (first floor)

The flooring on the second floor is rather weak, and therefore only lightweight goods, such as various types of lids, can be stored there.

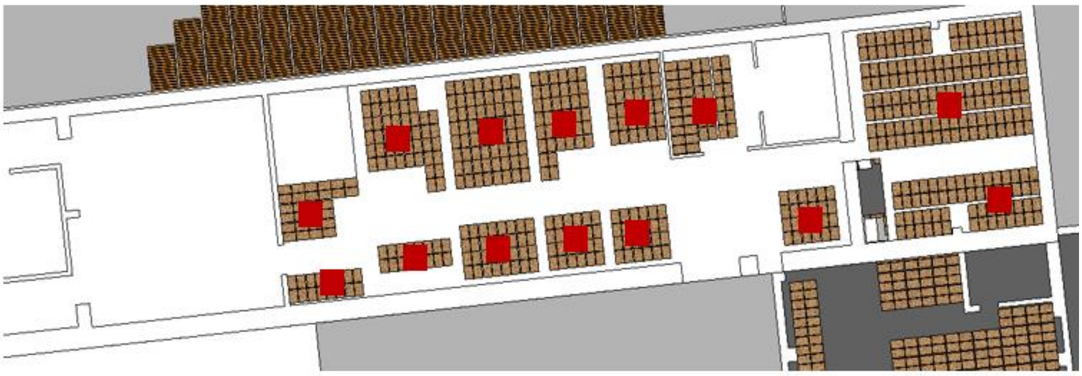


Figure 42. Location of goods based on colour zones in “Spritzerei” warehouse (second floor)

Articles were distributed across all floors in both “Blaserei” and “Spritzerei” warehouses in obedience to already fixed places for certain types of goods.

In “Blaserei” warehouse colours can be marked using flooring or walls on the ground floor. In “Spritzerei” warehouse with a height of no more than three meters, in addition to ground or wall signs, colour plates can be hanged on all floors. In “Blaserei” warehouse signs can be applied only on the mezzanine and cellar floors, as the height of the ground floor exceeds eight meters.

New warehouse

It was proposed to install pallet racking systems in the constructing warehouse. Referring to the theory, pallet racking systems are efficient and relatively cheap compared to other existing options. Keeping of numerous pallets in a framework permits to access any concrete pallet at any needed time, which is important in case of efficient loading and fast dispatch. In addition, pallets can be stacked as high as safe with this system, since racks are meant to be stable.

Block stacking as another possible solution that was suggested. Block stacking can be utilized in the new warehouse as it is the most popular storage form, which does not require any investments and can be applied in any open space of the warehouse.

As the repository is new and products should be extracted, it was concluded that new forklifts are going to be purchased in order to operate.

7.4.2 Optimization in terms of time

New lift

Delivery of the products to the first and second floors in “Spritzerei” warehouse takes too much time. The main reason for this is the congestion of products before delivery to the desired floor.

The first idea was the installation of a new lift with a larger capacity. However, interviewed employees stated that the facility is too old to replace the existing elevator with a new one.

Hire of new personnel

Two possible solutions were proposed concerning the hiring of new personnel, one of which coincided with the opinion obtained during the interviews.

A night carrier can be hired to overcome congestions, so goods will not be waiting at the collection point until morning. Since the interviews were carried out in January, at the beginning of this thesis work, FRIES has already hired a night shift worker. Nevertheless, depending on the number of operating machines, the company may need another forklift driver at night at any time.

Currently, there are two forklift drivers in “Spritzerei” warehouse. As another feasible decision, FRIES can hire one more warehouse worker during the day shift, so the roles will be divided as follows: goods will be transported to the lift by one of the warehouse workers whereas another will deliver them to the desired floor, on which the third worker will place them according to the colour zones.

ERP system

The case company is presently at the stage of evaluating a new ERP system to be aware of products´ location and to reduce searching time. For the system to work properly, it is necessary to reflect all warehouse processes and operations in “Blaserei” and “Spritzerei” warehouses using barcode labels. With regard to the new warehouse, in case of the installation of a pallet racking system, labelling of goods along with marking of racks can be utilized.

How product tracking can be reflected in the ERP system?

Alphanumeric zones can be established and applied in the ERP system. On the example of one of the storage rooms, the division into alphanumeric zones is demonstrated (see Figure 43).

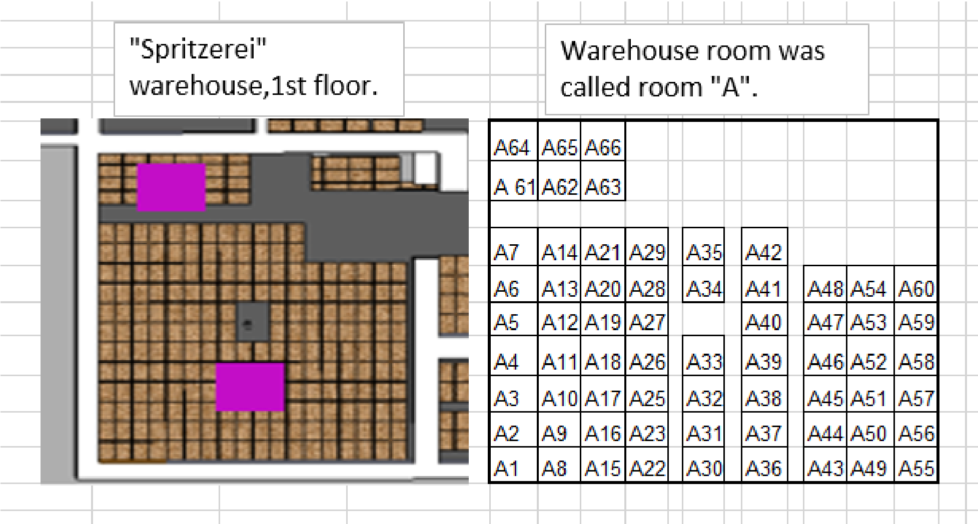


Figure 43. Alphanumeric zones

Each cell belongs to a pallet place. This system will assist to find out information about free pallet places in the warehouse, and searching time for required goods will be shortened.

For proper operation of alphanumeric zones, the management phase ought to be implemented in the ERP system. Extract from the table of such a management system is given in Table 8.

Table 8. Control system in ERP

March as an example of a controlled month.
Warehouse room "A".

	01.03.2019	02.03.2019	03.03.2019	04.03.2019	05.03.2019	06.03.2019	07.03.2019	0
A1	**VENDOR CODE**							
A2								
A3								
A4								
A5								
A6								
A7								
A8								
A9								
A10								
A11								
A12								
A13								
A14								
A15								
A16								
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A34								
A35								
A36								
A37								
A38								

The principle of the presented control table is as follows: after extracting pallets from the certain cells or delivery articles to the cells, this should be reflected in the table using the vendor code of the product in accordance with the date of collection or delivery. Free cells should be left without any supplier codes so that a warehouse worker can look at the table, find free cells and deliver goods to the selected place, taking into account colour zones.

This table has to be filled out and updated every day, even if items remain in the same places in order to provide better control.

Benefits from ERP with high integration of processes are displayed in Figure 44.

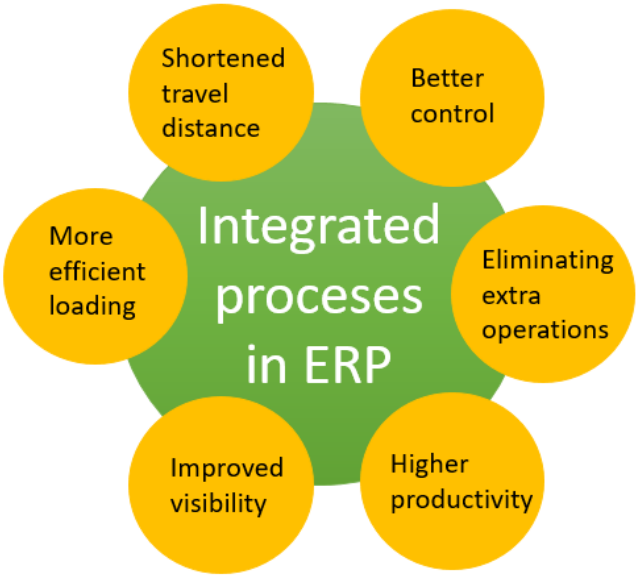


Figure 44. ERP benefits

By fully integrating of warehouse process into the ERP system, FRIES will get a number of benefits that contribute to the success of the company. Articles will be loaded more efficiently, and better control over warehouse operations can be obtained. Likewise, the travel distance of forklift drivers will be reduced due to a higher awareness of goods´ location. Integration of operations with the software will drive to elimination of unnecessary actions in the storage and will improve its visibility. As a result, higher productivity while operating will be achieved.

Limitations of ERP

FRIES is currently only evaluating and defining a new ERP system, and thesis results can be applied only after full development and launch of the system.

7.4.3 Costs of suggested improvements

On the basis of a meeting with the head of acquisition department in the company, the price of one litre of paint and colour wall signs, the price of a forklift and pallet racking system were discussed and determined.

Colour zones

One litre of paint costs approximately €25. While searching, it was detected that paint consumption per 1 m^2 is about 0, 05 litres. Taking into account room utilized for warehouses, case company should paint a total 280 m^2 to designate flooring in "Blaserei" and "Spritzerei" storages, and hence, purchase 14 litres of paint for €350 .

As for wall signs, it was revealed that the price of up to three kilograms of aluminium plates 600 x 400 x 3 mm is €3, 50. In case of purchasing more than three kilograms, the price is €7, 50. For FRIES, it is necessary to order about 130 aluminium plates, and the company should spend € 4,800, including all transportation costs. The more detailed calculation is presented in Appendix 12.

New warehouse

The price of a suitable forklift varies from €15 000 to €17 000. Main characteristics while searching were: operating height, capacity and forklift´s dimensions. Since the price is high, the case company can lease a forklift. The process of leasing implies the right to use the product in exchange for paying the rent for a specified period of time.

A pallet racking system for one pallet position costs from €45 to €350, including installation. Prices depend mainly on what type of pallet rack is needed. Gravity flow racks are considered the most expensive, while double deep and single deep are cheaper. Considering FRIES warehouse´s dimensions, pallet racking system will cost around €35 000.

Labelling

Based on the discussion with the head of the acquisition department, FRIES does not need to purchase labels, barcode printers or readers for the new warehouse. Constructing warehouse will be supplied with labels using existing equipment since it belongs to the "Blaserei" area, which is already equipped with its own tag printers and readers.

Hire of new personnel

At the meeting with the finance director, it was identified that in plastic and similar industries, the rate per hour for a warehouse worker is about €24 in a day shift and

€29 in a night shift. In accordance with the received hourly rates, it was calculated how much it would cost for the case company to hire a night shift or a day shift worker. Table 9 and 10 display calculations made.

Table 9. Company expenses for a day shift worker

Wage bill for a day shift forklift driver:		
	%	
Gross wage/month	100,00	2.200,00 €
Social insurance contribution company	21,48	472,56 €
Company employee care	1,53	33,66 €
Contribution for families	3,90	85,80 €
Contribution for chamber of commerce	0,39	8,58 €
Contribution for local community	3,00	66,00 €
Total cost/month		2.866,60 €
Holiday pay and Christmas bonus	16,67	477,86 €
Total cost for the company/month	152,02	**3.344 €**
Average hours of employment per month		135
Total cost per hour during a day shift		**24,77 €**
Total hours/year		1620
Total cost for the company/ year		**40.134 €**

Table 10. Company expenses for a night shift worker

Wage bill for a night shift forklift driver:		
	%	
Gross wage/month	100,00	2.200,00 €
Social insurance contribution company	21,48	472,56 €
Company employee care	1,53	33,66 €
Contribution for families	3,90	85,80 €
Contribution for chamber of commerce	0,39	8,58 €
Contribution for local community	3,00	66,00 €
Total cost/month		2.866,60 €
Holiday pay and Christmas bonus	16,67	477,86 €
Total cost for the company/month	179,98	**3.960 €**
Average hours of employment per month		135
Total cost per hour during a night shift		**29,33 €**
Total hours/year		1620
Total cost for the company/ year		**47.515 €**

7.5 Control phase

The aim of the control phase is to maintain changes to support improvements. At this stage, a control plan concerning provided changes was created. Forklift drivers have to be checked how well they know the location of certain articles, and therefore how well they have learned the colour zones. In case of buying a new forklift, drivers should be trained before using it not to damage or spoil goods.

Regarding the new ERP system, trainings should be organized and conducted to teach employees how to work in the new software. This is an essential phase in order to avoid possible mistakes and increase efficiency during operation.

8 Conclusions

The main objective of this research work was to provide a way to improve the warehouse and its processes, as well as to combine the results obtained with the ERP system at Fries Kunststofftechnik GmbH. In order to achieve better results, a research design with a sequence of all steps was developed.

This research work has shown that the research design with relevant research questions, appropriate methods for collecting and analysing data leads to results. Thereby, a plan with predetermined steps contributed to the identification of the root causes and secondary causes of the problems.

Root causes are related to the use of space and time. It has been determined that mismanaged inventory, manual data entry, inaccurate purchase orders, damaged items, lack of storage space and wasted storage space are the causes of inefficient use of warehouse space. Likewise, it was detected that the absence of a tracking system in the current ERP software in FRIES drives to inefficient time utilisation.

With regard to secondary causes, it was revealed that the lack of storage space hinders diversification of the products. Thus, the company cannot expand its product options to attract new customers.

Through interviews with employees with extensive working experience, participant observations in conjunction with in-depth analysis of data, the following conclusions were made: warehouse areas have to be marked and divided into zones and goods´ locations ought to be reflected in the new ERP software. In addition, the company should always have more space to store goods and enough personnel to get rid of congestions.

As a result, logistics operational efficiency, control over operations and attraction of new customers can be gained by introducing new products.

9 Discussion

9.1 Achieving the research objectives and answering the questions

In the Introduction part, research objectives, main and supporting research questions were stated in order to create a solid base for further work. Throughout the thesis work, it was significant to answer these questions and achieve set goals by means of research and analysis.

The research proved that efficient warehouse utilisation is crucial for the speed of work. Long searching time leads to breakdowns in the company's supply chain, such as long waiting time, delays and, thereby, to unsatisfied customers. Optimization of warehouse space was reached by providing schemes and a detailed description of their application in practice.

Any company that deals with logistics should have sufficient storage space. Lack of space brings to the employment of predetermined areas, such as parking places, courtyard areas or storage rooms, designed for predefined goods. Consequently, due to constant permutations, workers can be confused, and their operating efficiency will be reduced. Furthermore, the suspense of production and, hence, the absence of diversification are caused due to the lack of storage space, which can lead to loss of customers and income. The target with the lack of space was met by obtaining storage room for manufactured goods.

Based mainly on the ERP literature review, it was revealed that one of the most significant factors in a fast workflow is the correlation between ERP and warehouse processes. The goal was met by introducing a tracking system that can be used to be aware of the articles´ location and can also be reflected in the new software. Moreover, benefits after the introduction of the new ERP system are presented.

After all, all the research questions were answered, which directly brought to the achievement of the initial research objectives.

9.2 Reliability and validity of the research work

Reliability of this work can be guaranteed by the uncertainty of the final outcomes at the beginning of the thesis work. The research was conducted independently, without any influence from the case company or university, in order to avoid bias and any predetermined or desired results.

However, since it is impossible to completely avoid bias, it was minimised by choosing methodological triangulation and selecting participant observations, in-depth interviews and content analysis as data collection methods. All the data obtained was carefully verified through communication with the managers responsible for a specific area being studied and monitoring of the situation.

Validity of this thesis work insures the veracity of the research done and can be confirmed by a thoroughly built research design. The design of this study was established after referring to a number of relevant books in order to be sure of the steps to be taken, their sequence and application in practice.

This research work can be used while studying analogous problems in similar companies due to its reliability and validity. Thus, results received are credible and conclusive.

A critical look at the research work

Although the results are credible and can be used in comparable cases, if the study can last longer, the research questions may be deeper and cover more details. Hereby, the results could be more accurate.

Furthermore, in case of quantitative research, experiments can be carried out to determine the time of delivery of goods to the desired floors, as well as searching time using a stopwatch. The resulting numbers can be converted to tables or graphs and compared with the results after the improvement phase.

Regarding the methods of analysis, ABC analysis can be selected to determine the need for goods relocation according to the category "A", "B" and "C".

However, since the mentioned ways to improve the results are assumptions, they cannot be trusted until they are applied.

9.3 Ideas for further research

Fries Kunststofftechnik GmbH is an excellent example of how a company with a leading market position with products corresponding to all standards still faces some difficulties while operating. Thereby, the following ideas for further research are listed below:

1. Currently, the case company uses old warehouse facilities, and therefore it would be interesting to plan a warehouse layout and space utilisation for the new buildings, if they decide to replace the old with the modern ones.
2. Taking into account the location of the assembly and packing places in FRIES, it would be interesting to work on the planning of the replacement of the assembly site to reduce the number of actions taken and improve operational efficiency.
3. Due to the fact that Six Sigma is a quality and process improvement strategy, which is aimed to reduce the number of errors in the processes and come close to zero defects, it would be challenging but interesting to implement this methodology to detect failures during the production process in FRIES, which is primarily a manufacturing company.

All in all, in addition to the ideas listed above, there is a number of others for further optimization or development to comply the current needs of any large company with its own production, packaging, storage and loading areas.

9.4 Reflections on the research

I found the research work to be challenging at the beginning but satisfactory at the end. It was challenging, mainly because of the wide storage space, number of permutations of pallets and language in which I was conducting my work. Since the company is located in Austria, German was the main language of communication.

Over time, during my work, I learned a lot of new information regarding the practical use of the warehouse and its internal processes, which contributed to the growth of my professional skills.

I was supposed to find new solutions without any specific requirements or standards, which indicated the degree of responsibility. The research work required consistency, persistence, concentration, patience and a lot of time to provide valuable results.

References

Andrews, J. 2009. *A+ Guide to Managing and Maintaining Your PC.* 6th Edition. ISBN: 978-0538465038.

Bartholdi III J. J., Hackman S. T. 2011. *Warehouse & distribution science.* The Supply Chain and Logistics Institute. Accessed on 5 February 2019. Retrieved from https://www.scl.gatech.edu/sites/default/files/downloads/gtscl-warehouse_science_bartholdi.pdf

6 Basic Benefits to Adapting ABC Analysis of Inventory. 2017. Page on the SCMdojo website. Accessed on 27 January 2019. Retrieved from http://www.scmdojo.com/6-benefits-of-abc-analysis-of-inventory/

Berks, J. 1998. *Handbook of Simulation - Principles, Methodology, Advances, Applications, and Practice*. DOI: 10.1002/9780470172445. ISBN 978-0-471-13403-9.

Charantimath, P. M. 2006. *Total Quality Management.* Published by Dorling Kindersley. ISBN: 978-81-7758-647-3.

Cole, G. A. 1997. *Strategic Management.* 2d Edition. Printed in Singapore by Seng Lee Press. ISBN: 978-1-84480-087-2.

Company and history. N.d. Page on the Fries Kunststofftechnik GmbH website. Accessed on 20 January 2019. Retrieved from https://www.fries-kt.com/company/?lang=en

Crossman, A. 2017. *An Overview of Qualitative Research Methods*. Accessed on 12 of February 2019. Retrieved from https://www.thoughtco.com/qualitative-research-methods-3026555

Design Details: Costing Methods. 2018. Page on the Microsoft website. Accessed on 25 January 2019. Retrieved from https://docs.microsoft.com/en-us/dynamics365/business-central/design-details-costing-methods

Fabregas, K. 2018. *How to Create & Print Barcode Labels in 3 Steps.* Accessed on 10 April 2019. Retrieved from https://fitsmallbusiness.com/barcode-labels/

Faizal S. M. 2018. *The Five Essential Methods for an Efficient Warehouse Operation.* Accessed on 21 January 2019. Retrieved from https://sipmm.edu.sg/five-essential-methods-efficient-warehouse-operation/

Ferreira, A. Silva, C., Mesquita, C. 2013. *Advances in Sustainable and Competitive Manufacturing Systems,* Lecture Notes in Mechanical Engineering. Edited by Azevedo, A. DOI: 10.1007/978-3-319-00557-7_118.

Flowcharts, Storyboards and Rapid Prototyping. N.d. PDF document on Docplayer website. Accessed on 20 January 2019. Retrieved from https://docplayer.net/2524427-Chapter-12-flowcharts-storyboards-and-rapid-prototyping.html

Frechtling, J. 2002. *The 2002 User-Friendly Handbook for Project Evaluation.* 94 p.; Special section by Henry Frierson, Stafford Hood, and Gerunda Hughes. Available from National Science Foundation, Directorate for Education and Human Resources, 4201 Wilson Blvd., Arlington, VA 22230.

Freese T. L. 2000. *Warehouse layout and design.* Accessed on 2 February 2019. Retrieved from http://www.freeseinc.com/images/Warehouse_Layout_and_Design.pdf

Fusch, P., Fusch G. E., Ness, L. R. 2018. Denzin's Paradigm Shift: Revisiting Triangulation in Qualitative Research. *Journal of Social Change, 1,* 19-32.

Ghauri P.N., Grønhaug, K. 2005. *Research methods in business studies. A practical guide.* 3d Edition. Published by Pearson Education. ISBN: 0273 68156 7.

Grant, D. B., Trautrims, A., Wong, C. Y. 2015. *Sustainable Logistics and Supply Chain Management.* First published in Great Britain and the United States in 2013 by Kogan Page Limited. ISBN: 978-0-7494-7386-0.

Gwynne, R. 2011. *Warehouse Management: A complete guide to improving efficiency and minimizing costs in the modern warehouse.* First published in Great Britain and the United States by Kogan Page Limited. ISBN: 978 0 74946074 7.

Halseth, K. 2008. *Process Modelling & Mapping: The Basics.* Accessed on 21 February 2019. Retrieved from https://cdn.ymaws.com/www.bfma.org/resource/resmgr/articles/08_64.pdf

How Mobile Printing Benefits Warehouse Operations. 2013. Page on the Zebra Technologies website. Accessed on 4 February 2019. Retrieved from https://www.zebra.com/content/dam/zebra/white-papers/en-us/mobile-printing-benefits-en-us.pdf

Implementing Activity-Based Management: Avoiding the Pitfalls. 1998. Statements on Management Accounting – Statement Number 4CC. Published by Institute of Management Accountants in the United States of America. ISBN: 0-86641-268-9.

International Standard. 2005. *Quality management systems-fundamentals and vocabulary.* (ISO 9000:2005(E)) (3d ed.). Accessed on 26 February January 2019. Retrieved from https://www.sis.se/api/document/preview/906477/

ISO 19011. 2011. *ISO translated into plain English.* Accessed on 9 April 2019. Retrieved from http://www.praxiom.com/iso-19011.htm

Johnston, K. 2019. *Advantages & Disadvantages to Corporate Strategy Diversification.* Accessed on 25 February 2019. Retrieved from https://smallbusiness.chron.com/advantages-disadvantages-corporate-strategy-diversification-62119.html

Kennedy D. 2017. *Types of Material Handling Equipment.* Accessed on 22 January 2019. Retrieved from https://bizfluent.com/about-5868303-types-material-handling-equipment.html

Kenton, W. 2018. *Last In, First out – LIFO.* Accessed on 2 January 2019. Retrieved from https://www.investopedia.com/terms/l/lifo.asp

Kiisler, A. 2014. *Inventory management – basic concepts.* Accessed on 29 January 2019. Retrieved from https://www.vkok.ee/logontrain/wp-content/uploads/2014/03/Riga-3-july-2014.pdf

Kootanaee, A. J. 2013. Just-in-Time Manufacturing System: From Introduction to Implement. *International Journal of Economics, Business and Finance, 2,* 8-14.

Krippendorff, K. 2004. *Content Analysis: An Introduction to Its Methodology*. 2d Edition. Published by Sage Publications. ISBN: 0-7619-1544-3.

Kumar, C. R. 2008. *Research Methodology.* Published by APH Publishing Corporation. ISBN: 8131304191.

Lees, F.P. 1996. *Loss Prevention in the Process Industries 2nd Edition.* Published by Elsevier. ISBN: 978-0-7506-1547-1.

Linton, L. 2017. *Advantages & Disadvantages to Corporate Strategy Diversification.* Accessed on 22 January 2019. Retrieved from https://bizfluent.com/info-8006976-advantages-disadvantages-corporate-strategy-diversification.html

Levy, M. 2018. *A Holistic Approach to Lessons Learned: How Organizations Can Benefit from Their Own Knowledge.* Printed by CRC Press. ISBN: 978-1-138-56476-3.

Lock, I., Seele, P. 2015. Quantitative content analysis as a method for business ethics research. *Business Ethics: A European Review, 24,* 24-40.

Mahdi, A. Y. 2013. *Algorithm and Flow Chart.* Lecture1. Accessed on 20 February 2019. Retrieved from https://faradars.org/wp-content/uploads/2015/07/Algorithm-and-Flow-Chart.pdf

Malhotra, N. K., Nunan, D., Birks, D. F. 2017. *Marketing research: an applied approach.* 5th Edition. Published by Pearson. ISBN-13: 9781292103129.
Mand, J. S. 2013. Application of Lean and JIT principles in Supply Chain Management. *International Journal of Management Research and Business strategy, 2,* 86-87.

McLeod, S. 2017. *Qualitative vs. Quantitative Research.* Accessed on 20 January 2019. Retrieved from https://www.simplypsychology.org/qualitative-quantitative.html

Merritt, C. N.d. *Advantages and Disadvantages of ABC Analysis Inventory.* Accessed on 26 January 2019. Retrieved from https://yourbusiness.azcentral.com/advantages-disadvantages-abc-analysis-inventory-28187.html

Methods and Techniques of Observation. 2017. Page on the Word Press website. Accessed on 16 February 2019. Retrieved from https://pgdabm1618.wordpress.com/author/baseramegha/

Monteleone, E., Langstaff, S. 2014. *Olive Oil Sensory Science.* This edition was first published in 2014 by John Wiley & Sons, Ltd. ISBN-13: 978-1118332528. DOI: 10.1002/9781118332511.

Muller, M. 2003. *Essentials of inventory management.* Published in 2011 by AMACOM, a division of American Management Association in Printed in the United States of America. ISBN: 081441551.

Pallet racking systems. 2019. Page on the Pallet Racking Systems Limited website. Accessed on 26 January 2019. Retrieved from https://www.palletrackingsystemsltd.co.uk/faqs/what-are-the-different-types-of-warehouse-storage-systems/

Reman, T. 2019. *Inventory Management Basic Concepts.* Accessed on 24 January 2019. Retrieved from https://de.scribd.com/doc/97270254/Inventory-Management-Basic-Concepts

Sahin, A. 2008. Design for Six Sigma (DFSS): lessons learned from world-class Companies. *International Journal of Six Sigma and Competitive Advantage, 1*, 48-59.

Sarby, A. 2016. *SWOT Analysis.* Registered in England: 05448422. ISBN: 978-0-9932504-2-2.

Saxena, R. S. 2009. *Inventory Management: Controlling in a Fluctuating Demand Environment.* Published by Global India Publications Pvt Ltd. ISBN: 978-93-80228-21-1.

Schoenfeldt, T. I. 2008. *Practical Application of Supply Chain Management Principles.* Published in 2008 by American Society for Quality, Quality Press. ISBN: 978-0-87389-736-5.

Scott, R. 2011. *Benchmarking: A Literature Review.* Edith Cowan University. Accessed on 3 March 2019. Retrieved from https://intranet.ecu.edu.au/__data/assets/pdf_file/0010/357193/Benchmarking-Literature-Review.pdf

Seth, C. 2015. *The SWOT Analysis: A key tool for developing your business strategy*. Published by Lemaitre Publishing. ISBN: 978-2-8062-6932-4.

Shah, R. 2019. *What is ABC analysis? Advantages ABC Analysis and Disadvantages ABC Analysis.* Accessed on 27 January 2019. Retrieved from http://onlineaccountreading.blogspot.com/2015/01/abc-analysis.html

Supply Chain & Logistics Basics: Best Practices for Labeling the Warehouse. 2019. Page on the datex website. Accessed on 10 April 2019. Retrieved https://www.datexcorp.com/supply-chain-logistics-basics-best-practices-for-labeling-the-warehouse/

Taghizadegan, S. 2006. *Essentials of Six Sigma.* 1st Edition. ISBN: 978-0-12-370502-0. DOI: https://doi.org/10.1016/B978-0-12-370502-0.X5000-0

Tetteh, E. G., Uzochukwu, B. M. 2015. *Lean Six Sigma Approaches in Manufacturing, Services, and Production*. Published in the United States of America by Business Science Reference (an imprint of IGI Global). ISBN 978-1-4666-7321-2.

Types of Barcodes. 2019. Page on the Barcode labels website. Accessed on 6 April 2019. Retrieved from https://barcode-labels.com/getting-started/barcodes/types/

Vivekananthamoorthy, N., Sankar, S. 2011. *Lean Six Sigma, Six Sigma Projects and Personal Experiences.* Edited by Prof. Abdurrahman Coskun. Published by InTech. DOI: 10.5772/17288. ISBN: 978-953-307-370-5.

Walker M. 2018*. Spotlight on: 7 Key Warehouse Processes*. Accessed on 22 January 2019. Retrieved from https://www.logisticsbureau.com/spotlight-on-7-key-warehouse-processes/

Warehouse Inventory management. 2019. Page on the Icepts website. Accessed on 26 January 2019. Retrieved from http://www.icepts.com/tag/warehouse-inventory-management/

Warehouse Labels & Identification. 2019. Page on the asg services website. Accessed on 4 February 2019. Retrieved from http://www.asgservices.com/warehouse-labels

10 Ways to Improve Your Warehouse Inventory Management. 2017. Page on the Silver Lining storage website. Accessed on 26 January 2019. Retrieved from https://blog.silverliningstorage.in/10-ways-to-improve-your-warehouse-inventory-management

What Are the Different Types of Warehouse Storage Systems? 2019. Page on the Pallet racking systems website. Accessed on 20 January 2019. Retrieved from https://www.palletrackingsystemsltd.co.uk/faqs/what-are-the-different-types-of-warehouse-storage-systems/

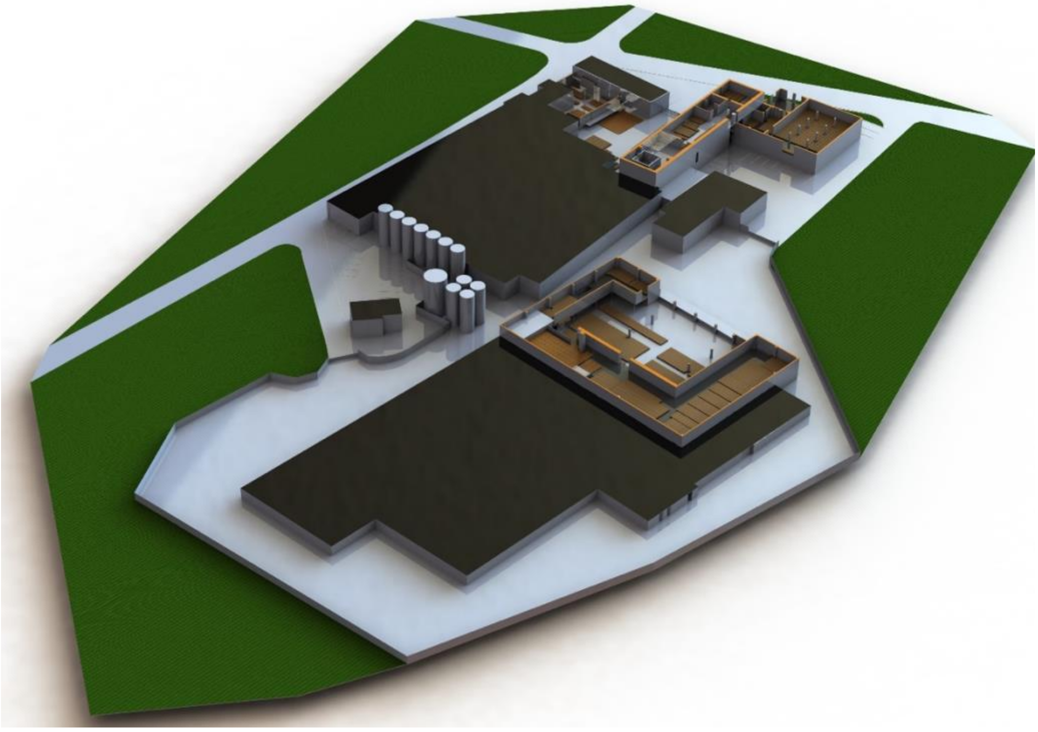
Wilson, P. F., Dell, L. D., Anderson, G. F. 1993. *Root Cause Analysis: A Tool for Total Quality Management.* Printed by BookCrafters. ISBN: 0-87389-163-5.

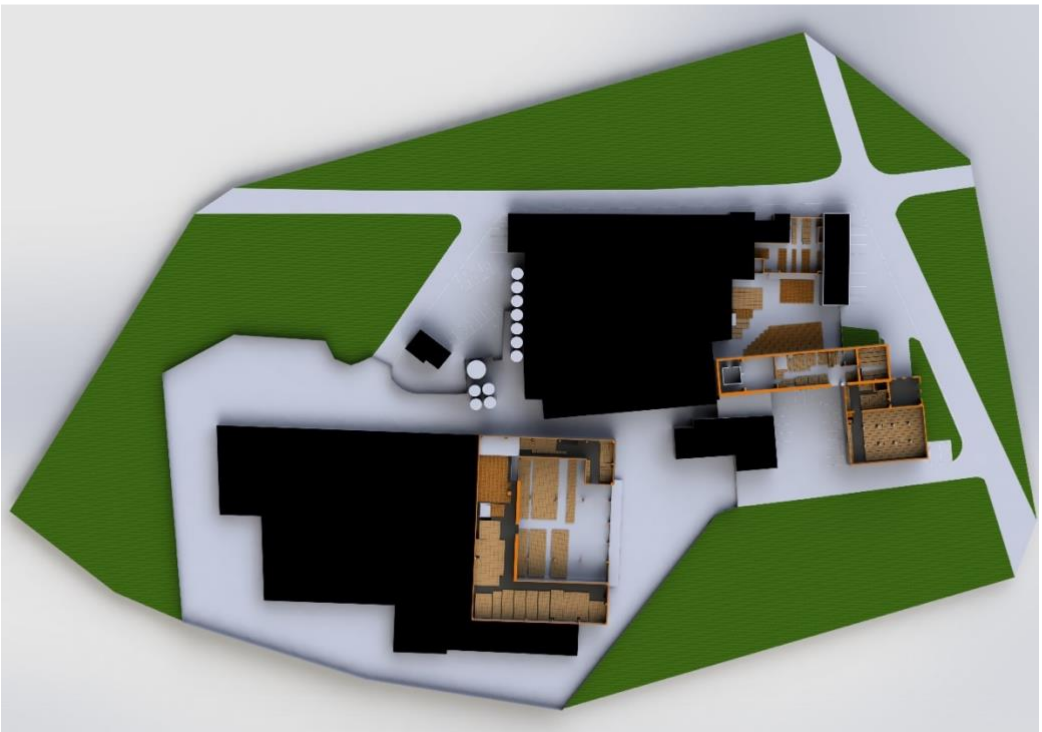
Yam, K. L. 2009. *Encyclopedia of packaging technology, Third Edtition.* ISBN:9780470541395. DOI: 10.1002/9780470541395.

Yin, R. K. 2003. *Application of cash study research.* Printed by SAGE in The United States of America. ISBN: 0761925511.

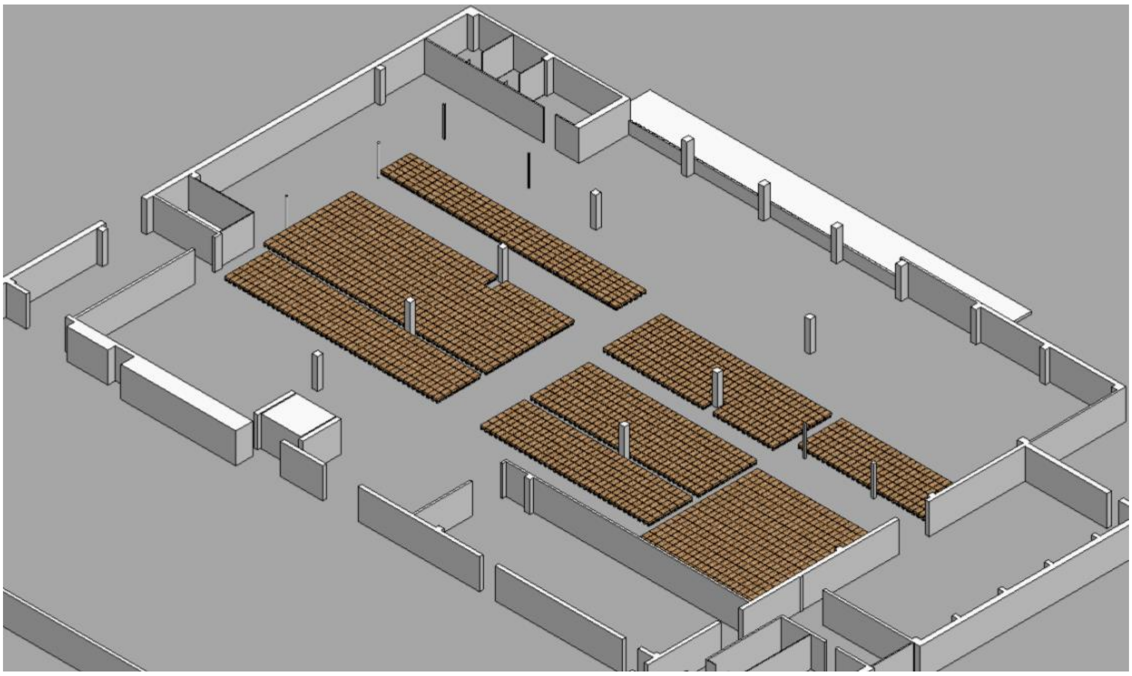
Appendices

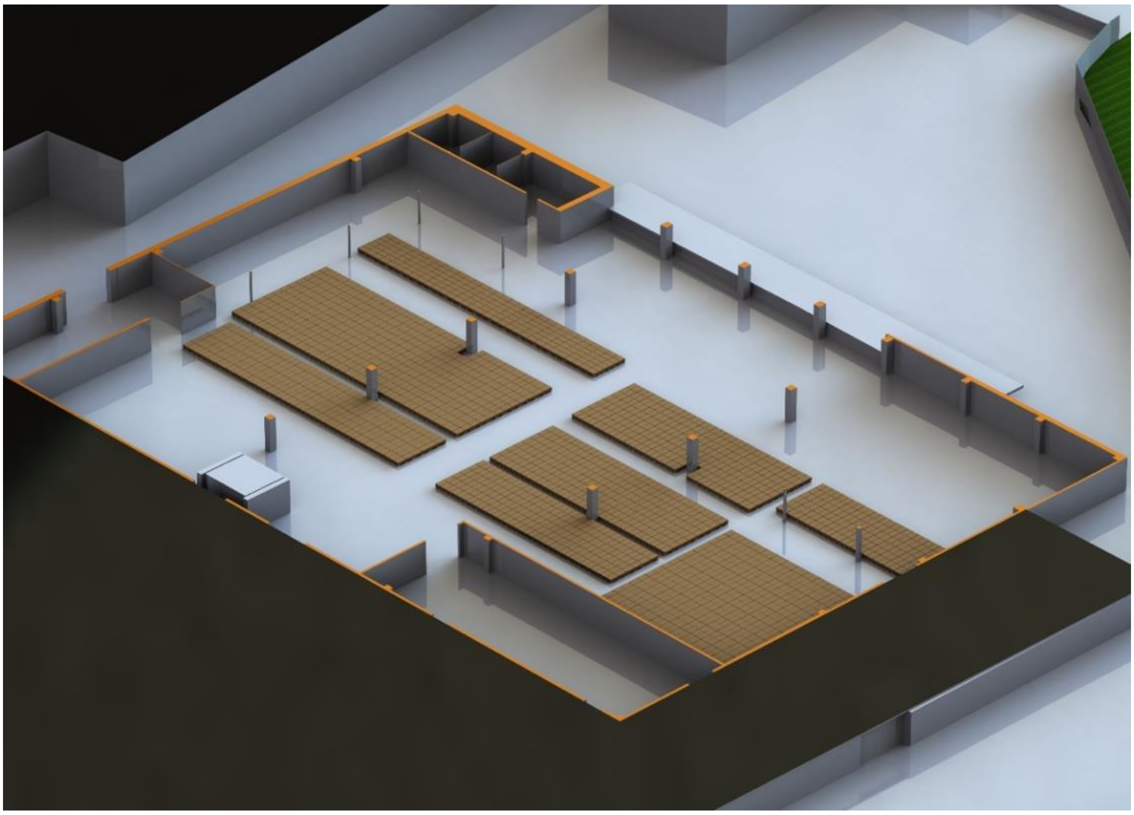
Appendix 1. Total storage area in FRIES



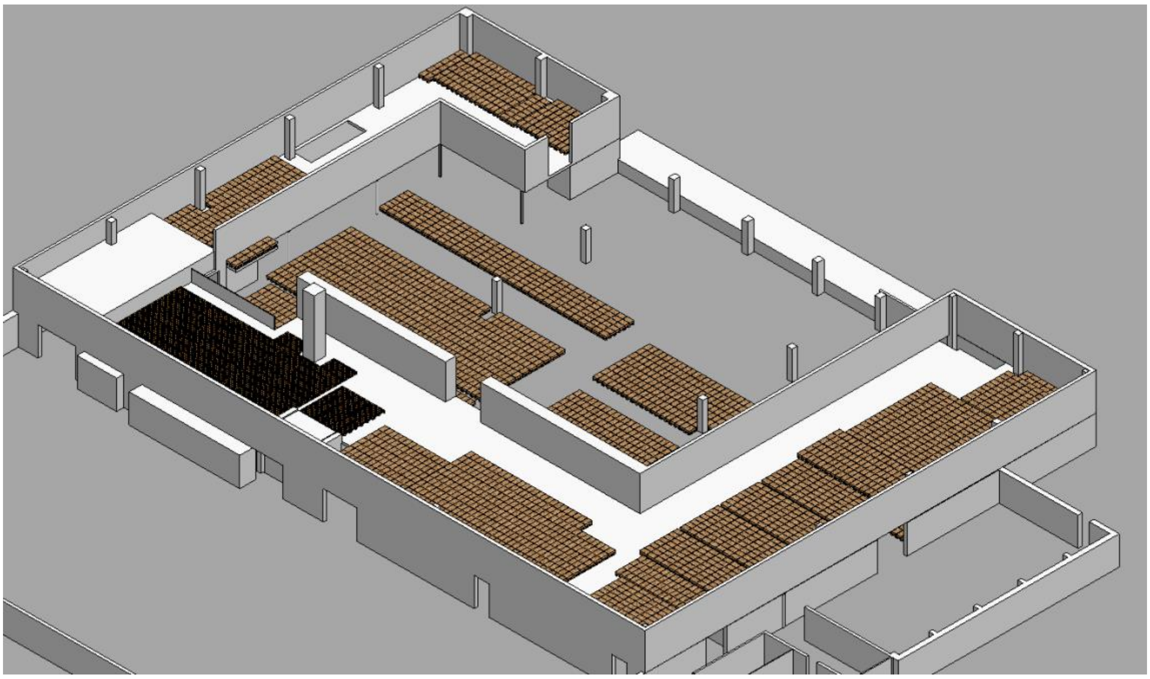


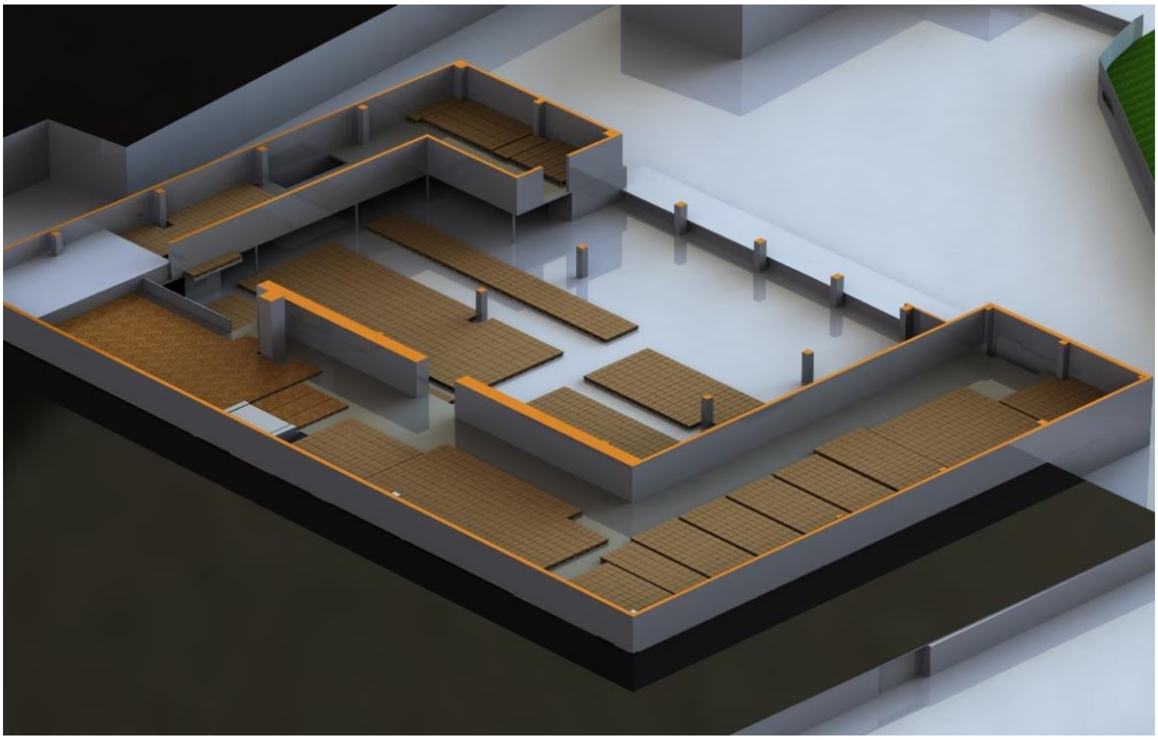
Appendix 2. 3D model of "Blasereilager" (ground floor)



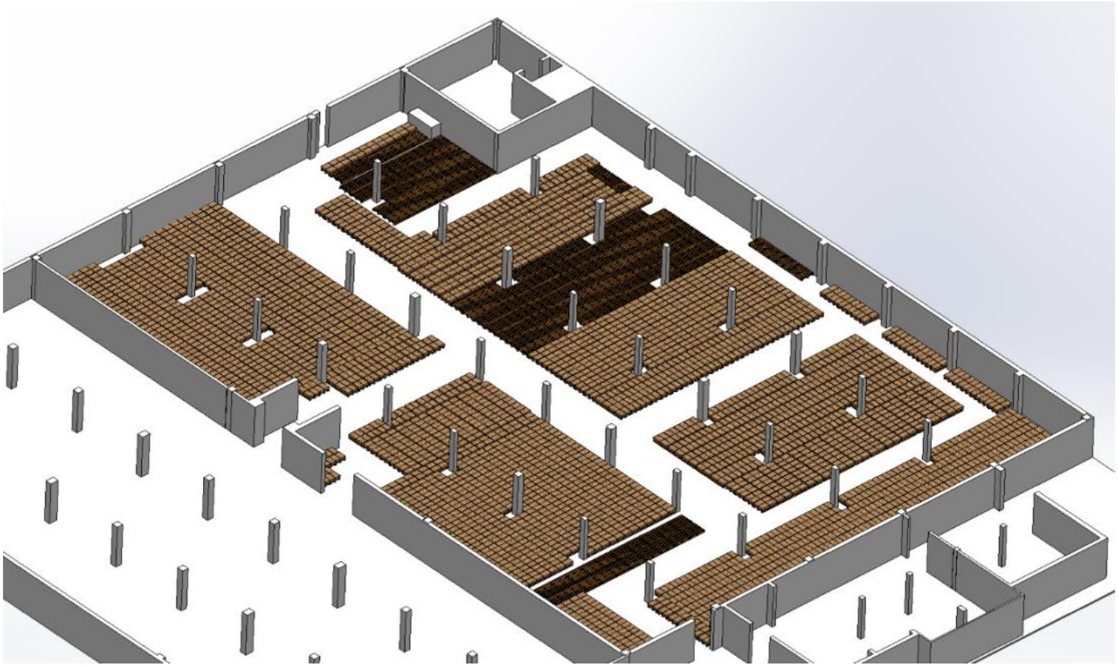


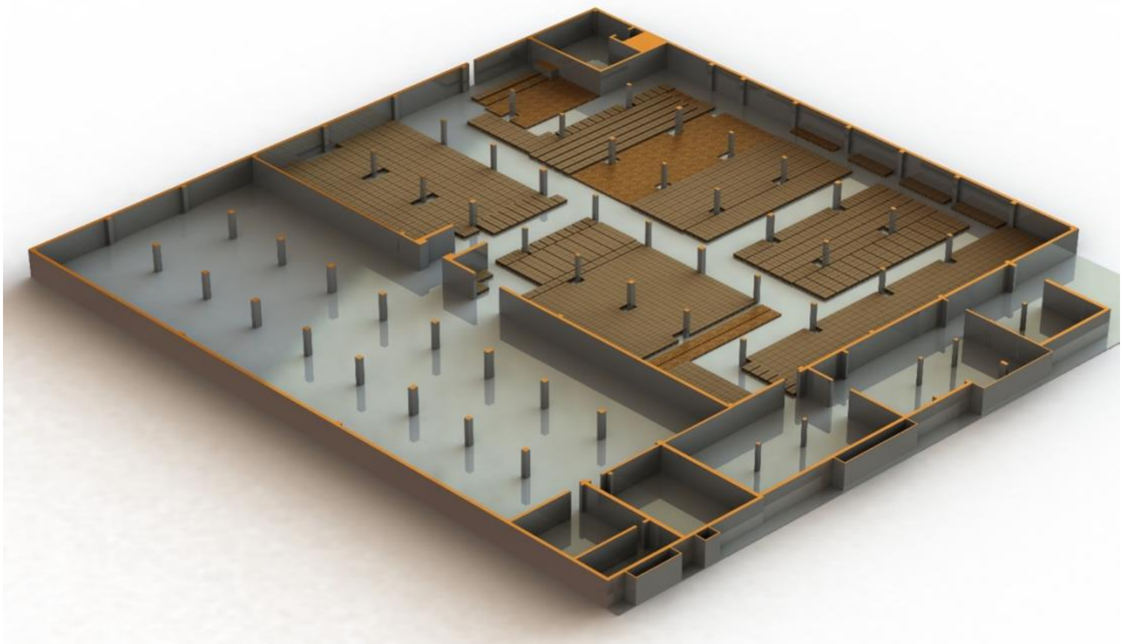
Appendix 3. 3D model of "Blasereilager" (ground and mezzanine floors)



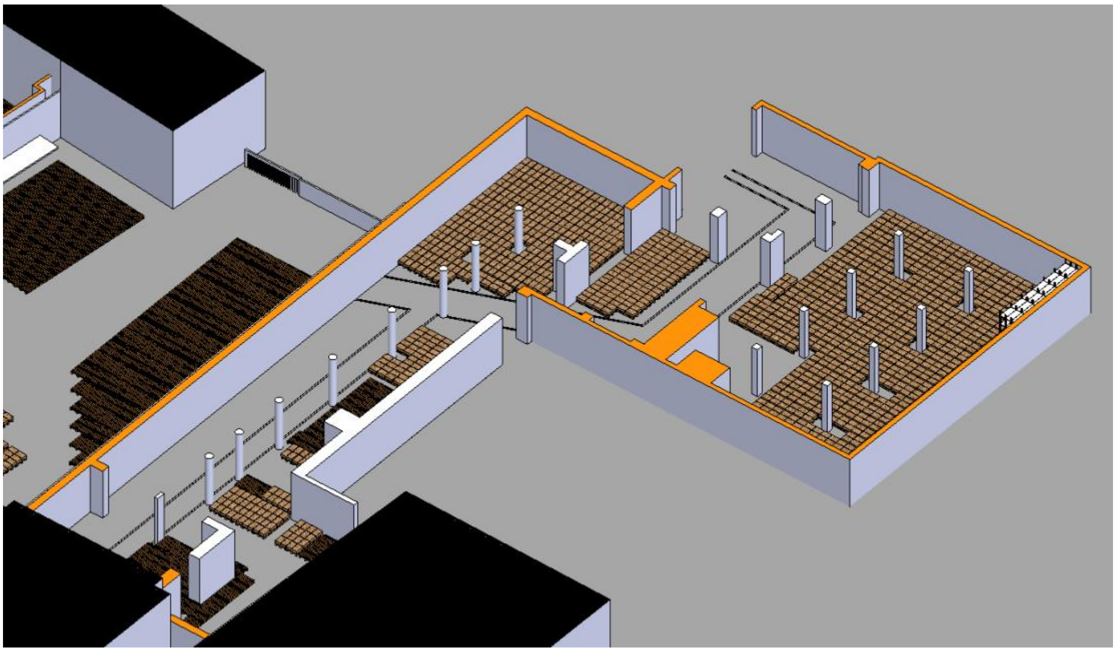


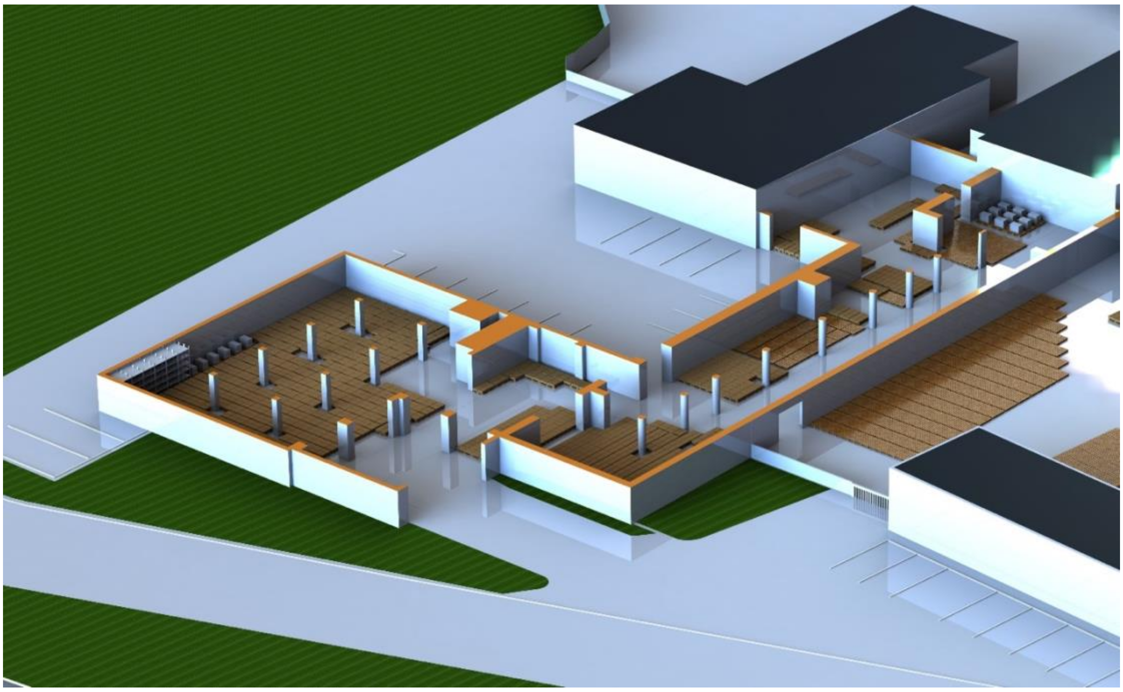
Appendix 4. 3D model of “Blasereilager” (cellar floor)



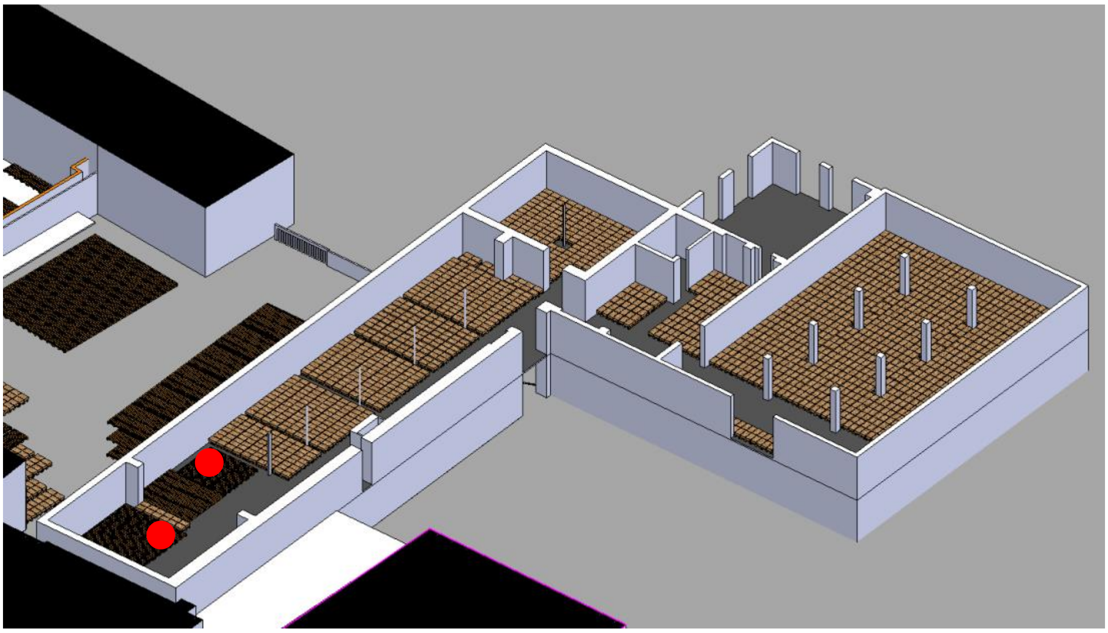


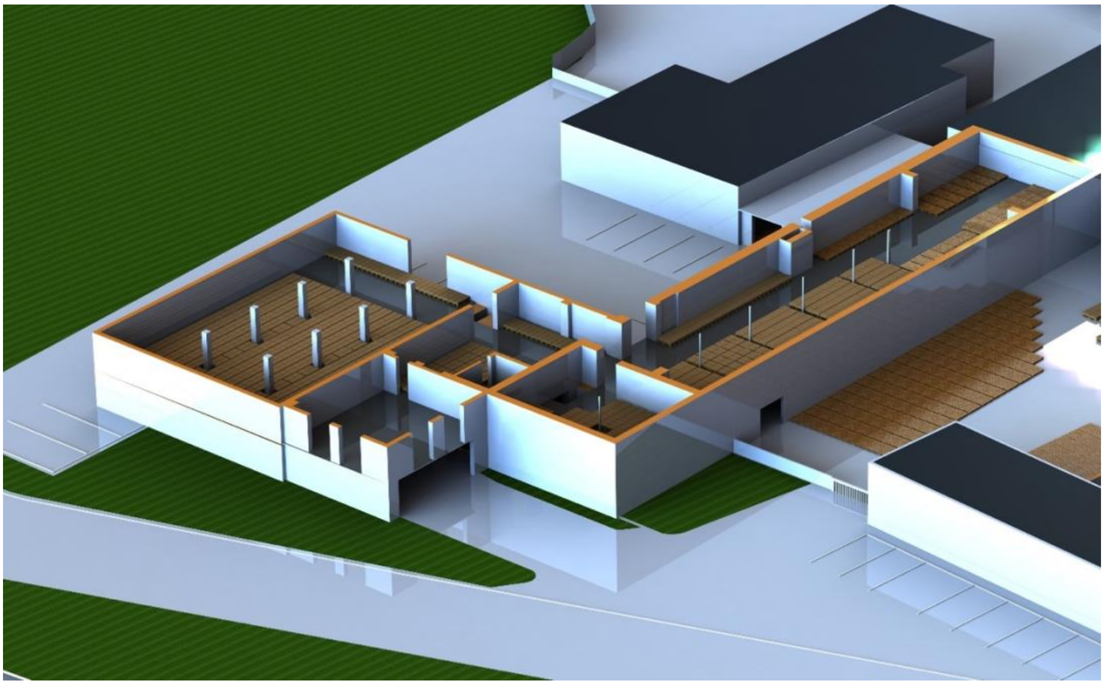
Appendix 5. 3D model of “Spritzereilager” (ground floor)



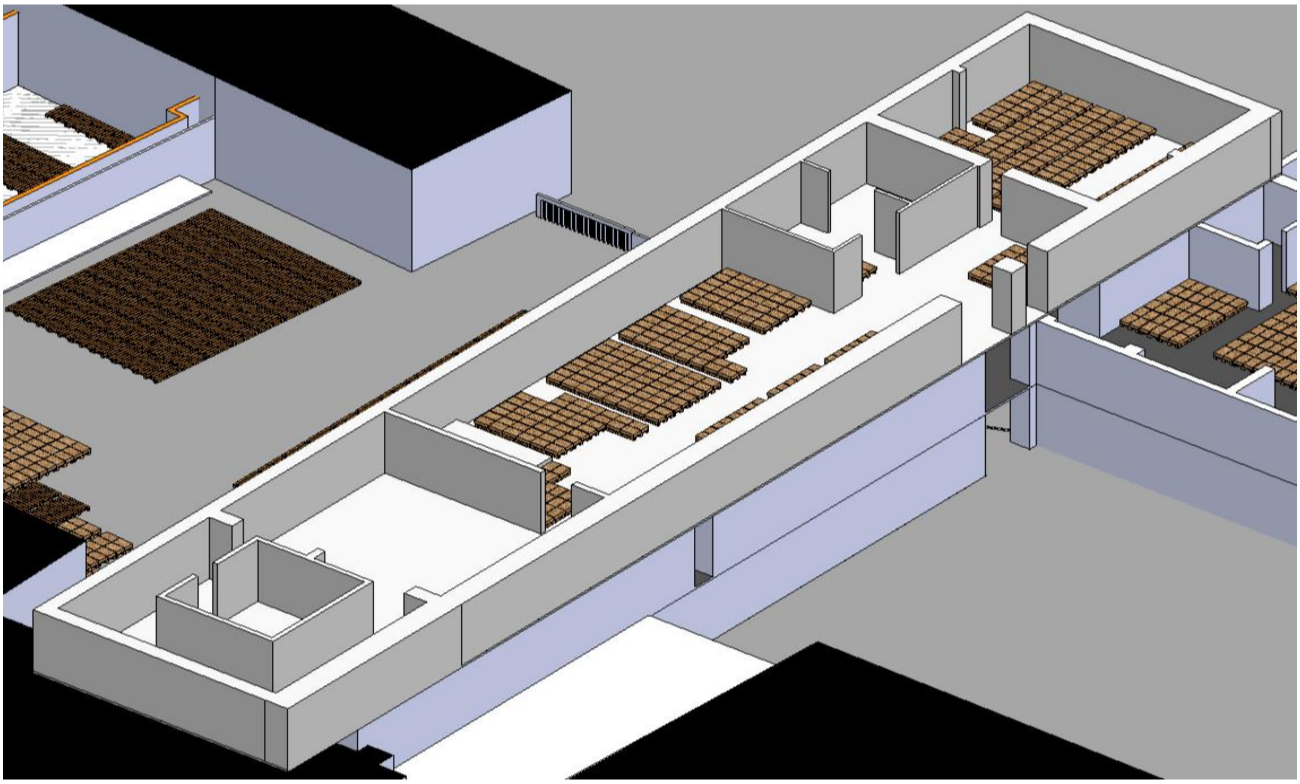


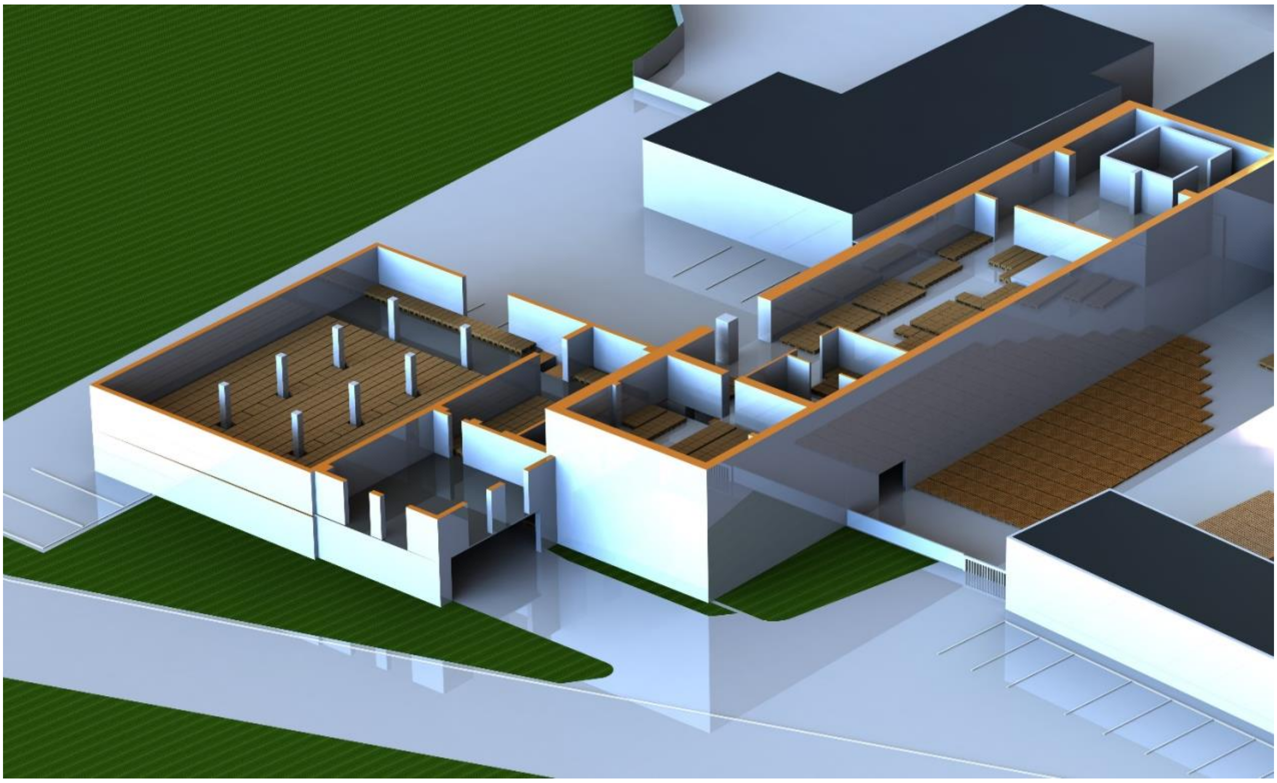
Appendix 6. 3D model of "Spritzereilager" (first floor)



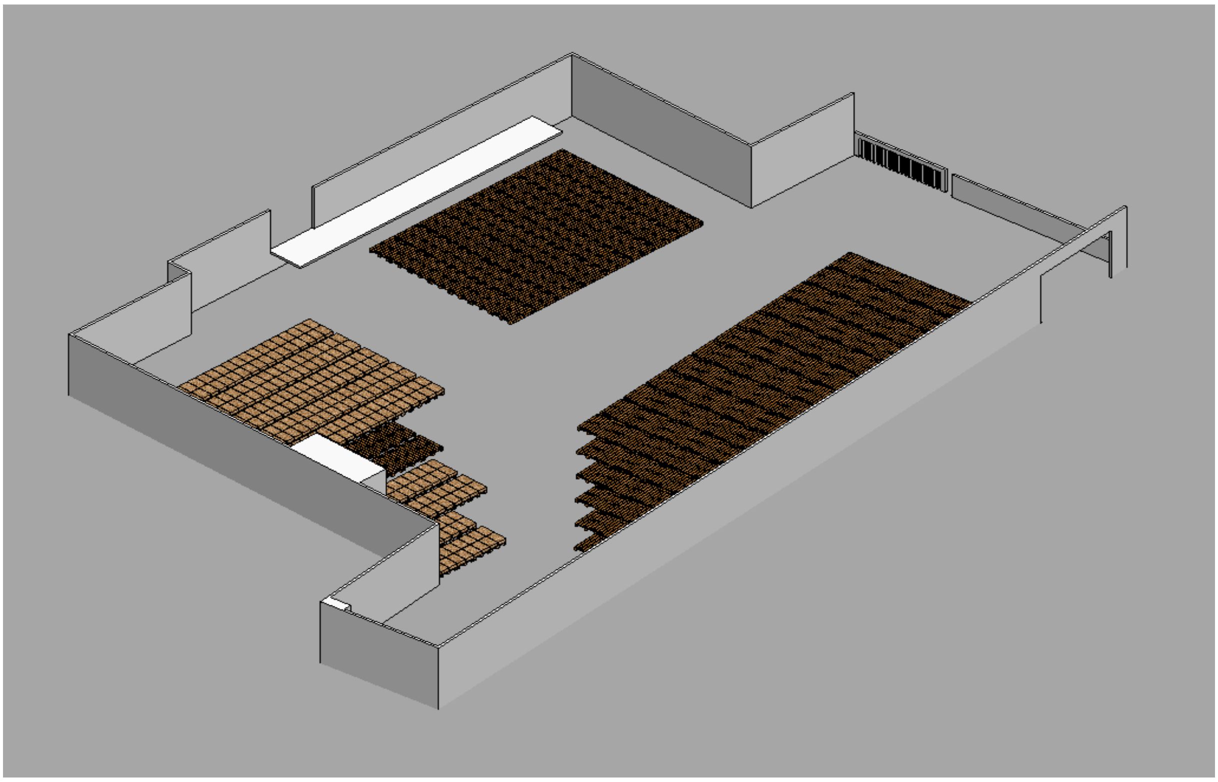


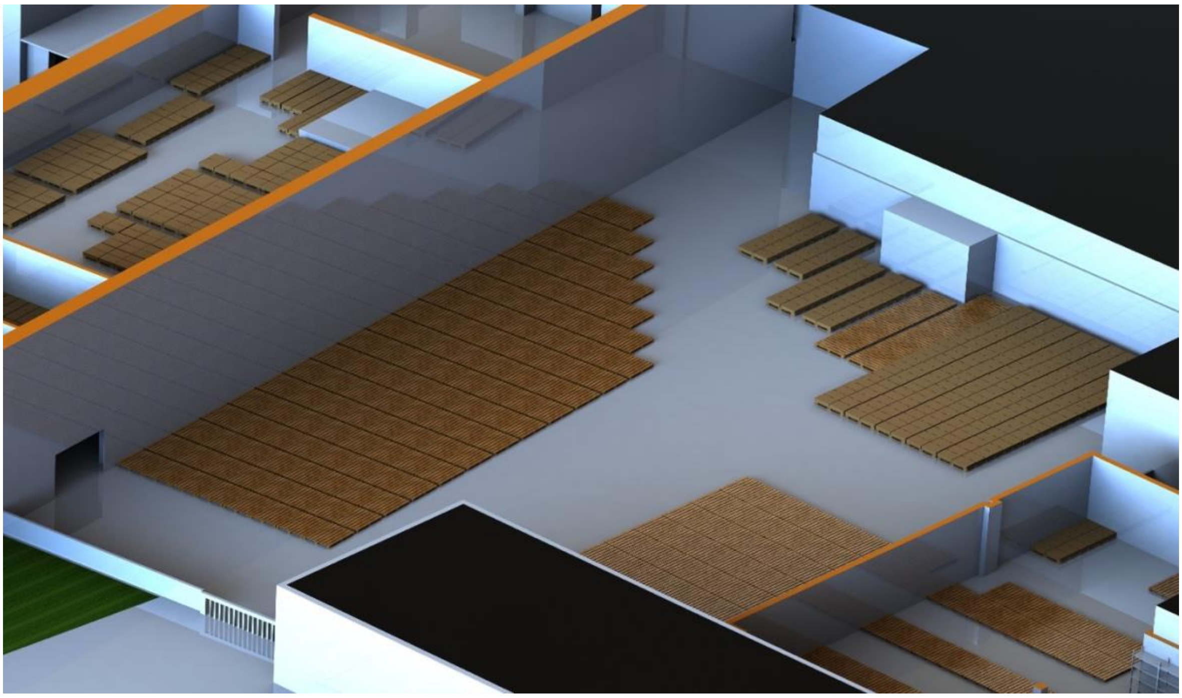
Appendix 7. 3D model of "Spritzereilager" (second floor)



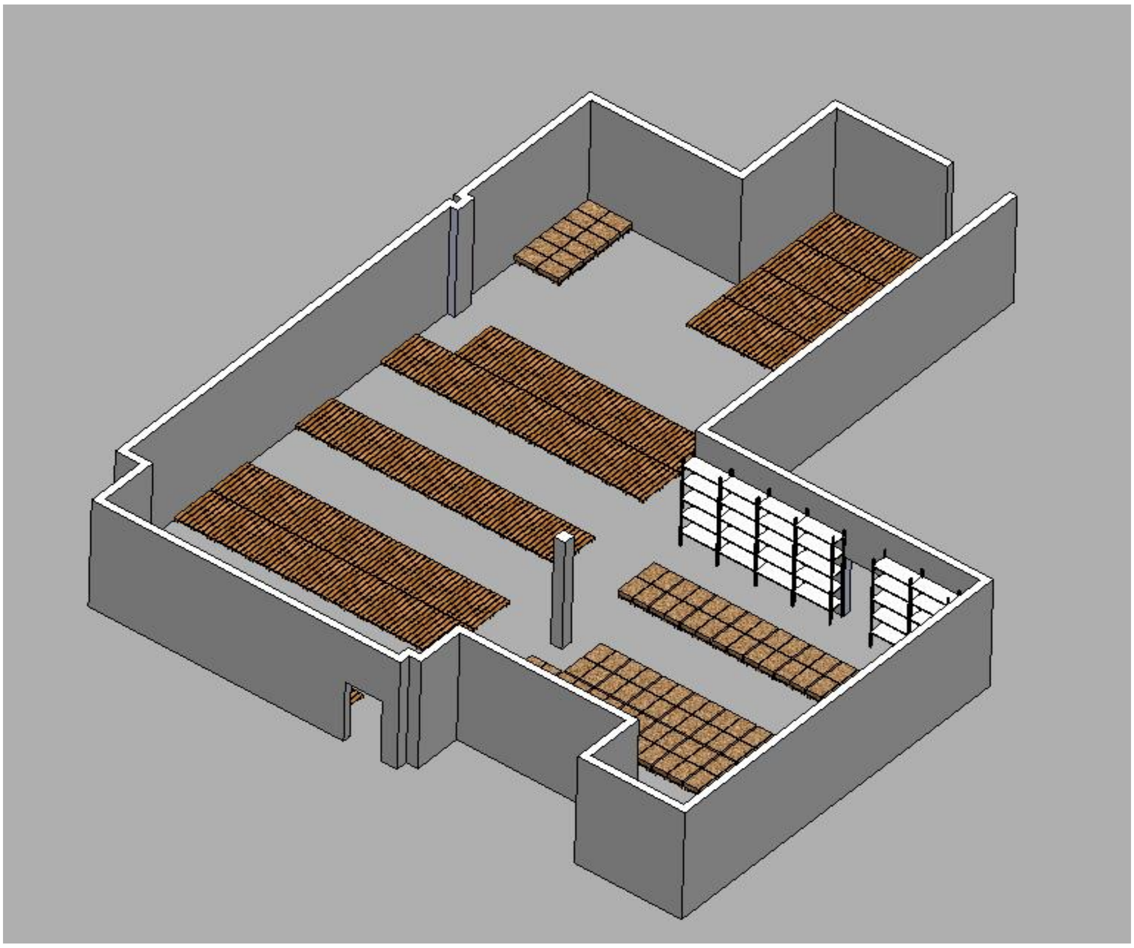


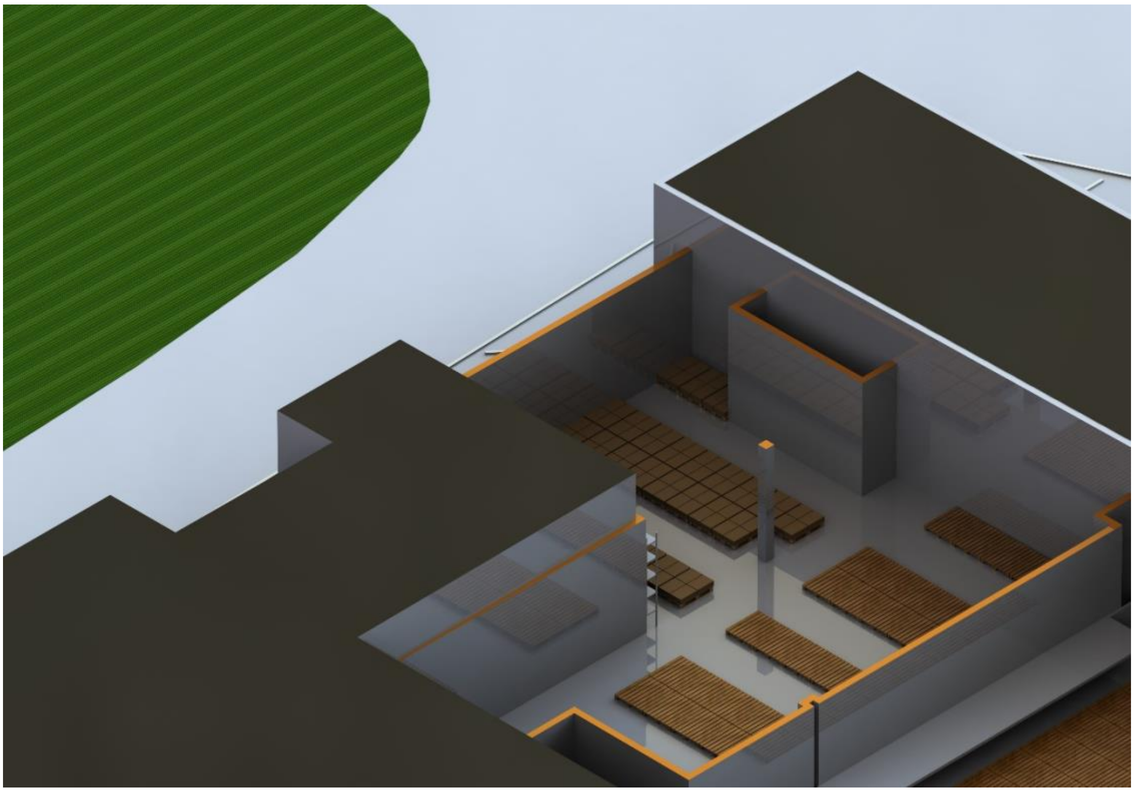
Appendix 8. 3D model of "Hoflager", warehouse in the yard zone





Appendix 9. 3D model of "Zwischenlager"





Appendix 10. Interview questions (English version)

Interview questions:

1 a. How was it determined that the warehouse space is used inefficiently?

1 b. What are the causes of inefficient warehouse usage?

2 a. How was congestion of goods found out in the warehouse?

2 b. What are the causes of the congestion?

3 a. How was it discovered that the company has lack of free storage space?

3 b. What are the causes for the lack of free storage space?

4 a. How was turned out that goods´ location is not defined?

4 b. What are the causes of products´ location uncertainty?

Appendix 11. Interview questions (German version)

Interviewfragen:

1 a. Wie wurde festgestellt, dass die Lagerfläche ineffizient genutzt wird?

1 b. Was sind die Ursachen für eine nicht effiziente Lagerplatz Nutzung?

2 a. Wie wurde der Stau von Waren im Lager herausgefunden?

2 b. Was sind die Ursachen der Überlastung?

3 a. Wie wurde festgestellt, dass es dem Unternehmen an freien Lagerflächen fehlt?

3 b. Was sind die Gründe für den Mangel an freien Lagerflächen?

4 a. Wie hat sich herausgestellt, dass der Warenstandort nicht definiert ist?

4 b. Was sind die Ursachen für die Standortunsicherheit von Produkten?

Appendix 12. Price offer

FRIES Kunststofftechnik GmbH
Schützenstraße 19
6832 Sulz

Angebot	**34324**
Datum	02.04.2019
Kunden-Nr.	214602
Ihre UID-Nr.	ATU68081639
Versandart	10 GLS / ab Werk
Sachbearbeiter	Peter Wagner
Telefon	+43 (0)5572 3766-119
	peter.wagner@visuform.com

Anfrage Schilder Metall

Wir danken für Ihr Interesse an unseren Produkten und bieten wie folgt an:

Pos.	Bezeichnung	Menge	EH	Einzelpreis	Gesamtpreis
1	**Aluminiumschild** Material: Aluminium Größe/Stärke: 600 x 400 x 3 mm Oberfläche: roh Kanten: entgratet BESCHRIFTUNG Folientyp: 3M-S-Cal 50er Serie Farbtöne: 11 verschiedene Farben pro Seite Ausführung: beidseitig KONFEKTION Ecken: spitz Bohrungen: 2 Bohrungen längsseitig, Stand 20/20, DM 5 mm	130	Stk.	30,87	4.013,36
2	**Verpackungskosten nach Aufwand** bis zu 3 kg: € 3.50 ab 3 kg: € 7.50 Palette: € 19.50	1	Stk.		
3	**Transport- bzw. Versandkosten**	1	Stk.		
	Netto				4.013,36
	MwSt. 20%				802,67
	GESAMT			EUR	**4.816,03**