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Layout design planning of a logistics center

A study on space utilization after merger of two warehouses

Master of Science Thesis
in the Supply Chain Management and Production Engineering Programme

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Cover:
[Warehouse facility subjected to the redesign,
page 28.]

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Abstract

The purpose of this Master Thesis is to propose the new layout design of the combined warehouses, so that it can sufficiently accommodate the operations of two companies as well as enable improvement of space utilization and process efficiency. The case study was chosen as the approach of the research. Therefore, the study was conducted and developed in the hosting companies, Agility and Amring, located in Arendal in Sweden. For the following research, the data was collected by using various methods, like literature review, observations, and interviews. This thesis employed mixed of quantitative and qualitative approach in order to collect data and perform empirical study. The analysis of the empirical findings was based on the combination of two step-by-step procedures for facility planning. Systematic Layout Planning led to obtaining three different layout alternatives. Whereas Systematic Handling Analysis complemented the study by making comparison between suggested alternatives in terms of travel time and distance. After taking into consideration various aspects of the layout design as well as constraints, one layout was chosen and suggested as the best option. It was concluded that two concepts used in the project are supplementary and led to achieving break-even between space utilization, time and travel distance, and flexibility, which was required by the case companies.

Key words: Facility layout design, layout planning, SLP, SHA, space utilization, warehouse merger, logistics center

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Gothenburg, August 2016

Dziękuję,
Marta Rosińska

ధన్యవాదాలు
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List of Abbreviations

3P: Third Party Logistics

SLP: Systematic Layout Planning

SHA: Systematic Handling Analysis

WMS: Warehouse Management System

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1. Introduction

This section will present the introduction to the concept of layout planning and the general background of the research. This will be followed by a problem formulation, aim and research questions as well as limitations of the thesis. Finally, the outline of the project will be described.

1.1 Background

Due to the globalization and rapid growth of the logistics industry, the increasing number of logistics centers can be noticed. Logistics center is usually referred to the warehouse or other specialized facility dedicated to logistics operations (Liu et al., 2015). Warehouse is the link in the logistics system, in which goods are temporarily stored before they are routed to the subsequent links in the supply chain network (Garcia-Diaz et al., 2009). It acts as a buffer in order to meet both supply and demand. Goods stored in the warehouse might vary from raw materials to finished goods. One of the aims of the warehouse is to deliver goods to the customer in the right time, quantity and optimal cost (Venkatadri et al., 2014). The main processes that occur in the warehouse are storage and handling. However, it can offer more services as the third party logistics provider depending on the customer requirements. The dominance of the specific processes depends on the function that warehouse has (Garcia-Diaz et al., 2009).

The facility planning has recently gotten more attention since it has become part of the strategy for the successful logistics center (Tompkins et al, 2003). For decades, people used to follow the gut feeling in the process of designing the new layout. However, it is difficult to design complex logistics centers based only on the experience. Hence, more and more scholars have started research on the development of the layout planning. Gradually, more advanced methods have emerged.

According to Tompkins (2003), proper layout of the warehouse can improve safety, increase the performance and storage capabilities as well as provide better working conditions for the staff. Undoubtedly, the material flow can be improved and amount of damaged goods during handling and storage can be minimized. Proper planning of the warehouse also has impact on improving customer service and lowering the logistics costs. Designing the new storage facility must include simplifying and shortening transportation time and distance, merging or elimination of operations, space requirement and many others (Tompkins et al, 2003).

Introduction to study case

The following paper focuses on the two case companies that are subjected to the merger with each other. The initiator of this thesis project was Agility AB which is one of the world's largest integrated logistics providers with more than 20 000 employees worldwide and operations in approximately 100 countries. It acquired more than 40 logistics brands around the world, investing billions to build a global network with a strong footprint in emerging markets (Agility, 2015). In Sweden, company operates in 6 cities, including

Gothenburg. Currently, the distribution center, that is located in Arendal, employs 25 people and serves 19 different customers within 10,000m^2 warehouse. The main activities of the company concern warehousing but also repacking, pick and pack, and software updating for navigation systems. Agility has recently developed a collaboration with a retail and wholesale company in the tire industry, Amring AB. It is owned by the Dutch company, PON, an international trading and service group with about 13,000 employees in 20 countries. In 2013 Amring AB moved into a new logistics center near the port of Gothenburg in Arendal. The total warehouse area is 20,000m^2 and gives employment to 76 people (Amring AB, 2014). Amring AB handles and distributes tires and rims to the Nordic market.

Agility is going to manage entire logistics operations of Amring, including warehousing in Arendal. The reason behind this change is that Amring has recently faced money losses due to the seasonal variation in demand. To work on this problem Amring decided to collaborate with Agility since they have competence and knowledge in the supply chain management. Agility wants to optimize Amring's current inventories by decreasing it by 50%. What is more, Agility plans to move its warehouse to Amring's current premises by July 2016. The total area of Amring's warehouse is 20,000m^2, in which 8,000 to 12,000m^2 will be used by Amring and the rest 8,000m^2 will be dedicated to Agility. Both companies hope to optimize the space utilization including their small production lines, by reducing bottlenecks as well as decreasing high costs related to staff, equipment and layout.

The challenge is to combine two warehouses that deal with different operations and processes. Each company is facing problems connected to the lack of storing space as well as minor issues related to the efficiency of the small production units. What is more, they use different warehouse management systems that cannot be integrated for the first few years of the collaboration. However, aspects like human resources and in-house infrastructure can be shared between both parties. Moreover, Amring is dealing with the seasonal variation, whereas Agility provides solutions for the various customers with their own specific requirements. These aspects also have to be considered while designing the new layout.

1.2 Purpose

The purpose of this Master Thesis is to propose the new layout design of the combined warehouses, so that it can sufficiently accommodate the operations of both Amring and Agility as well as enable improvement of space utilization and process efficiency.

1.3 Research questions

In order to meet the purpose of the Master's thesis, the researchers will answer the following questions:

RQ1: What are the different activities inside the warehouse of both Agility and Amring?

For the better understanding of the current layout and space utilization, it is crucial to evaluate and get an idea of the organisations' functions and warehouse operations. Identifying the different activities inside the warehouse constitutes the base for the further investigation of the requirements for the layout planning. Being familiar with the company's profile is essential in order to proceed with any kind of strategic planning.

RQ2: What are the correlations between various warehouse operations as well as space requirements for each activity performed by both Agility and Amring?

It is of high importance to examine the relationships between various departments within the company. It is even more crucial in case of merging two warehouses, in order to determine the potential for combining or eliminating operations, which in turn, might result in optimizing space utilization or transportation distance (Tompkins et al, 2003). What is more, the data regarding space requirements is necessary to plan the new layout in such a way that all operations fit within walls of the existing facility.

RQ3: How can two warehouses be combined into one with the focus on the cost effective utilization of space, travel time and distance? (What results can be obtained by different layout alternatives, focusing mostly on the cost effective utilization of space, travel time and distance?)

When suggesting new potential warehouse layout, it is important to give different alternative solutions and compare them with each other in order to choose the most optimal one. The qualitative layout design based on Systematic Layout Planning (SLP) method as well as the quantitative assessment based on Systematic Handling Analysis (SHA) method will lead to choosing the optimal solution.

The expected result of the thesis project is to design the new layout for the combined warehouses of Agility and Amring. The suggestions will be given on how to maximize the storage space utilization as well as decrease travel time and distance. The result of the new facility layout will be subjected to this research question and supported by the previous two research questions.

1.4 Scope of the study

The thesis will not analyze any external activities, the focus remains in the warehouse activities and layout planning. Therefore, the project does not consider any activities like, purchasing processes, sales, distribution, forecasting, supply chain management, etc. The project will focus only on the activities connected to Amring's and Agility's warehouses located in Arendal, Gothenburg. The analysis of the data will be limited to the investigation of the available area, requirements for the future warehouse design, and simplified description of the processes and products. The focus does not lie in the inventory management or production flow optimization. Therefore, aspects like Warehouse Management System or production improvement methods will not be discussed.

Moreover, planning the warehouse layout design is subjected to the limitations in the contract between both case companies. The contract details will not be described due to the confidentiality, however, they might influence some decisions and suggestions regarding layout.

1.5 Outline of the report

Theoretical framework -This section provides a reader with the theoretical background relevant for this project. It gives the explanation to the concepts like layout planning, space utilization, and continuous improvement.

Methodology - This chapter describes the research methodology that was implemented in the project in order to achieve its aim. The work process is illustrated which covers aspects like research approach and data collection. At last, the validity and reliability of the research are assessed.

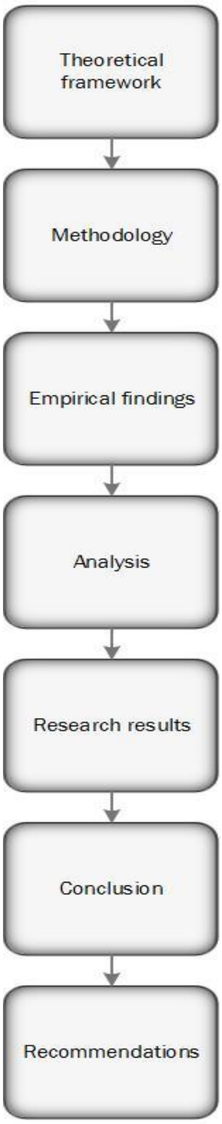
Empirical findings - This chapter is divided into two sections describing each case company respectively. Each section starts with the description of the company and its function. Next, the customers, operations and current flow are presented. The section is concluded with the outline of the current layouts and space requirements.

Analysis- In this section, authors analyze collected data and follow the SLP steps in order to create alternative layout designs. Three alternatives are further assessed using SHA technique.

Research results – Obtained results of study are presented and the optimal solution is chosen in this chapter. The justification behind the decision is stated as well.

Conclusions –This chapter sums up the study for master thesis project.

Further recommendations – In this chapter, authors give the recommendations to Agility and Amring for the future, regarding chosen layout. The ideas for the further study, that would be complementary to the presented project, are given.



2 Theoretical Framework

This section provides a reader with the theoretical background relevant for this project. It gives the explanation to the concepts like layout planning, space utilization, and continuous improvement.

2.1 Third Party Logistics

More and more often, companies involve external operators in their logistics processes. It is the solution that aims to decrease the cost of running logistics department, and at the same time to improve customer service and increase profit. One of the common practices is Third Party Logistics. 3PL can refer to a single function, or the whole group of logistics activities (Percin, 2009). The most common are: transportation, warehousing, cargo consolidation and the consolidation of customs, distribution and transportation management (Waters, 2003). The origins of 3PL solutions are in the eighties of the last century. Back then the usefulness of the IT sector increased significantly, which played an important role in the development of logistics. Many companies providing logistics services to its customers began to appear - many of them still work today (Chu, 2004)

Many companies around the world appreciated the assistance of external logistics operators (Waters, 2003). Among the most important advantages of this solution are: the ability to focus on other, more strategic areas of business rather than logistics, cost reduction of logistics management, competitiveness improvement of the company, no need to invest in logistics, increased quality of services provided by the company (Gudehus et. al, 2009).

2.1.1 Logistics Center

The logistics center is a facility with own organization and infrastructure dedicated to the various independent companies enabling them to perform logistics operations on goods (Liu et al., 2015). The operations are connected with storage and movement of goods between the sender and the recipient, including support for intermodal transport and providing customers with various additional services (Gudehus et. al, 2009).

2.1.2 Warehouse Management

The process of storage is a set of actions that are performed during the flow of goods through the warehouse, from receiving goods from external transport, by accepting, storing, picking, and shipping by the external means of transport (Hamdan,et. Al, 2008). In order to enable warehouse processes, certain technical and organizational conditions must be provided. They include aspects such as storage space, where activities will be performed, machinery and equipment, with which operations will be carried out or personnel (Richards, 2014). The complexity of the storage process is affected by many factors such as the function of a warehouse in the supply chain, the characteristics of the stored goods, magazine capacity, or the structure of receiving and delivery system (Faber et. al, 2013). Warehouse management practices and warehouse planning aim to coordinate all functions of the magazine for achieving the greatest effect with the least expenditure of human labor and company's resources. The warehouse management is to ensure the rational storage of material goods (Garcia-Diaz et al., 2009). Rationalization of the warehouse management is to allow the structuring, the best possible execution of tasks and the effort reduction of employed personnel (Scioscia, 2014).

The improvement of warehouse operation is influenced by many factors such as space, equipment, and people. Quantity, seasonality, and high bay storage are only some of the guidelines, according to which the layout of the assortment in stock is done. The choice of technical equipment is an important issue as well (Farahani et. al, 2011).

2.2 Optimization of space utilization

A proper understanding of the concept of the product movement zone is the key to make the appropriate selection of forklift and storage systems that maximize space utilization (Bragg, 2011). Managers of distribution centers and warehouses struggle with lack of efficient use of storage space, therefore lower costs, and choice of goods transfer solutions that are specific for their needs. The product flow analysis helps to understand the „needs" of warehouse It leads to solutions for aspects like product movements and inventory management that increase productivity and reduce costs (Richards, 2014).

2.2.1 The selection of forklift and racking system

An effective warehouse layout design must take into account an increasing number of inventory items while making better use of available plant space (Tompkins, 2003). In order to meet different needs, one can choose from the variety of forklift and racks types. Each has a specific storage function. For example, the racking system includes selective pallet racking, narrow aisle rack system, drive-through, drive-in, gravity flow racks, and many others. The choice of the forklift type important to use the warehouse space effectively (Rushton et al., 2006). Counterbalanced forklift requires a broad, 3-meter pass whereas a reach truck require a narrow passage of approx. 2.3 m. the very narrow aisle turret truck is the most space-friendly because the passage of approx. 1.7 m. Trucks which allow working in narrow aisles enable storage of more pallets positions and help to transform transport paths into efficient storage space. Apart from the smaller width of the aisle, reach trucks take advantage of the height of the warehouse, making a better use of the space available at higher levels (Cappella, 2015).

For example, in case of four levels storage, reach truck can store more than 20 % of the pallets in the same space, compared to a standard counterbalanced truck. On the other hand, turret truck increases this space by 30 % compared to the standard counterbalanced truck. In case of 9 levels storage, the same forklift increases the density of storage by 70% (Rushton et al., 2006).

2.2.2 Optimizing storage space

Different warehouses use various storage methods and different types of racks or mezzanines. The combination of different types of storage systems is extremely important in maximizing the usable space. The storage equipment storage be selected based on the movement of livestock (Ten Hompel et al., 2007).

Pareto principle (or 80/20 rule) refers to the movement of inventory in warehouses. This thumb rule states that approximately 80% of the activity in the warehouse comes from 20% of the products, which are frequently transferred inside the building. Next 15% of the activity is derived from the 30%stock keeping units (SKUs), which mobility rate is defined as the average. Finally, 5% of the activity comes from 50% of the inventory, which are stored in a slow manner. By separating the fast, medium and slow-moving products within the plant and increasing access to products requiring the highest activity, the throughput can be increased significantly.

Moreover, by facilitating access to these products, additional time can be gained to transfer the products inside the building (Ackerman, 2013).

Parts with high turnover are usually stored in warehouses with high volumes using pallet racking with standard width passes. Companies that have a reach truck can store products with a high turnover in places where there are narrow aisles. Products with an average circulation are more suitable for storage in narrow aisles. Lastly, it is suggested to store slow-moving products in a very narrow aisle by trucks with rising cabin. However, this is only theory that aim to support the decision how to store goods. Depending on the situation and needs, the scenario might be different (Ten Hompel et al., 2007).

2.2.3 Search for storage opportunities

Companies should put an effort in identifying additional ways to increase storage capacity or warehouse design performance. For example, the space located at the intersection of the two passages can be arranged as an area for storage. Another possibility is to use the space above the entrance gate by installing special racks. By examining the opportunities to use the available extra space, facility managers can gain much more effective solution (Federal Supply Service, 1969). Understanding the number of inventory items (SKU) depending on the demand for pallet positions is extremely important for the optimal utilization of the available storage space. In addition, managers should estimate the turnover rate for each item in inventory. According to Bragg (2011), such an information will help to decide on how the goods should be transferred and which storage system should be implemented, considering rack height and width of required passage.

By properly configured storage space and properly adjusted system of transfer of materials, productivity can be significantly increased and overall storage costs may be reduced (Ten Hompel et al., 2007).

2.2.4 Flexibility

An increasing competition in the logistics industry, make companies to adjust to the changing markets as much as possible. Therefore, the distribution centers and warehouses have to be designed in a flexible way so that they meet the various requirements of customers (Richards, 2014). What is more, there is no single manner in which the facility can be organized, neither there is an ideal solution for the particular warehouse. The most optimal layout plan is the one that can satisfy both, present and future operational requirements, considering the possible growth, changing customers, and product profile. According to Richards (2014) the design should be also inexpensive to adapt and scalable. One of the ultimate solution that could be implemented to the flexible warehouse is mezzanine floor. If it is not required at the moment of designing the usable space, it might be introduced in the later stage when the need for more utilized capacity arises (Richards, 2014).

It is believed that flexible design of a warehouse is based on the trade-offs between, space utilization, travel distance, accessibility, cost, safety, and many others. It does not matter if company is building a new facility or moving to an existing one, the above aspects should be taken into consideration while designing or re-designing the layout (Richards, 2014).

2.3 Procedure for Facility Layout Planning

The Systematic Layout Planning (SLP) is a design process developed by Richard Muther in 1965. This procedure remained as a systematic procedure for planning of many facilities as warehouses, hospitals, production plants, etc. It is a step-by-step procedure allowing the planners to identify and visualize the relationships between processes and finding the different alternatives for the layout design (Tompkins, 2003). The process can be described and executed in 10 steps that are depicted in Figure 2 and described below.

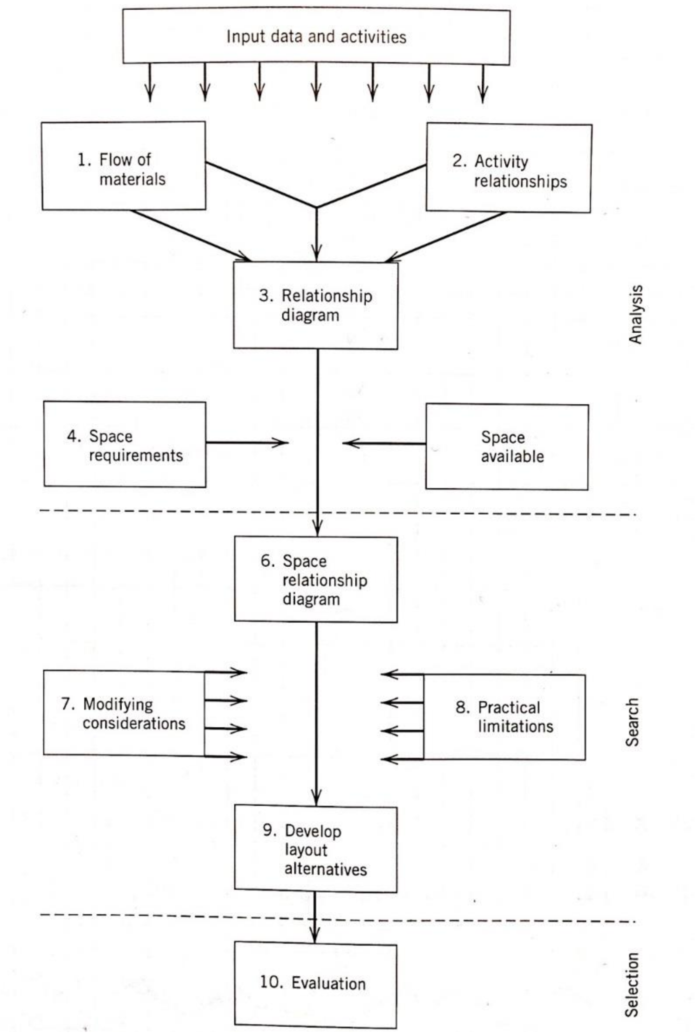


Figure 1 *Systematic Layout Planning Procedure (Tompkins, 2003)*

Input data and activities

In order to execute the systematic layout planning procedure, the necessary data should be collected first. Input data to be gathered consists of five important key elements (Tompkins, 2003):

Product: What type of product does the facility handle?

Quantity: What quantity of products does the facility handle?

Routing: What are the steps do the different products go through?

Supporting services: What are the value adding services that support the facility?

Time: How long the processes have to be executed?

Step 1: Identify the flow of material
The material or product flows are aggregated into a form of chart that visualizes the flow density between the different areas in the warehouse (Tompkins, 2003).

Step 2: Activity Relationship Diagram
The step activity relationship performs qualitative analysis, indicates the closeness of relationship between activities and resources. The results of the analysis are displayed in the activity relationship chart. The chart indicates which entities are related to others and also rates the importance of the closeness. This chart is one of the key element of the SLP, as it shows the importance of the relation between activities and makes a clear view on planning the arrangements of the facility. The relationships are made by closeness rating system and also the reason why the closeness is required (Tompkins, 2003).

A: Absolute necessary.

E: Especially necessary.

I: Important to be close.

O: Ordinary closeness is required.

U: Unimportant to be close

X: Should not be close to each other.

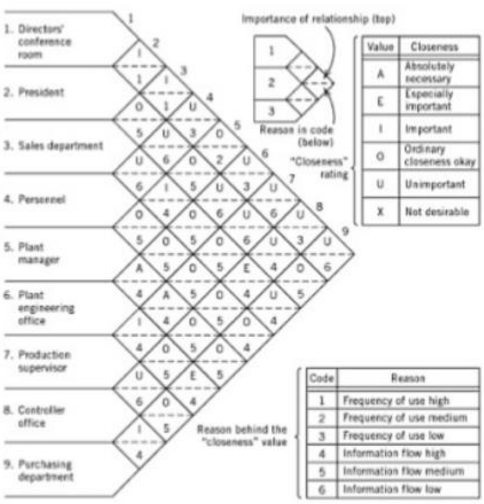


Figure 2 *Example of activity relationship diagram (Tompkins, 2003)*

Step 3: Relationship Diagram

The result obtained from the activity relationship matrix, those departments that should be close and or not are placed in the proximity. The relationship diagram is a visual display of the activity relationship chart (Tompkins, 2003).

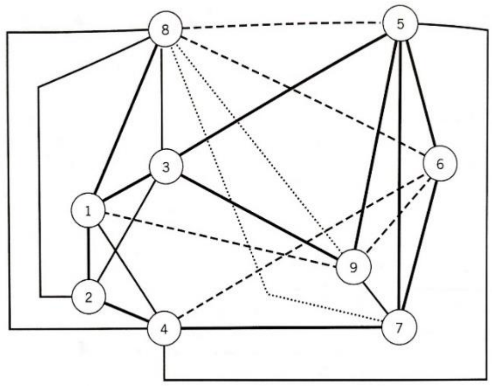


Figure 3 *Example of relationship diagram (Tompkins, 2003)*

Step 4: Space Requirements

Once the relationships are identified, the space required for each activity should be identified and analyzed. The information that should be gathered here are amount of space required in total, space required by the equipment used, operational space requirements, storage area space requirement, etc. (Tompkins, 2003).

Step 5: Space Available

At this step the total space availability is analyzed. The space is assigned to each activity based on the space requirement. But when performing the detailed layout, it is necessary to analyze the space requirements and assign the spaces accurately as per available place and for future expansions (Tompkins, 2003).

Step 6: Space Relationship Diagram

The result obtained from integrating space available and space requirements are put in the activity relation diagram by indicating the space allotted for each department or activity. This is mainly used to visualize the result obtained (Tompkins, 2003).

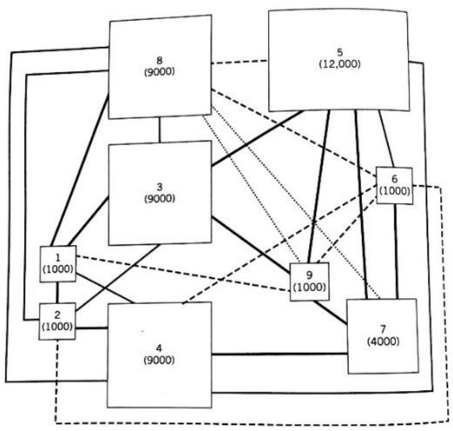


Figure 4 *Example of space relationship diagram (Tompkins, 2003)*

Step 7: Modifying the considerations
This step is to identify the constraints and modify them. The constraints are obtained from the previous step, in terms of space and inter activities challenges (Tompkins, 2003).

Step 8: Limitations
The limitations in terms of budget, space availability, and infrastructure have to be identify and taken into consideration before moving to the next step (Tompkins, 2003).

Step 9: Develop alternative layouts
This step involves development of alternative block layouts. The block plan is developed from the space availability information and other relationship charts that have been obtained from the previous steps (Tompkins, 2003).

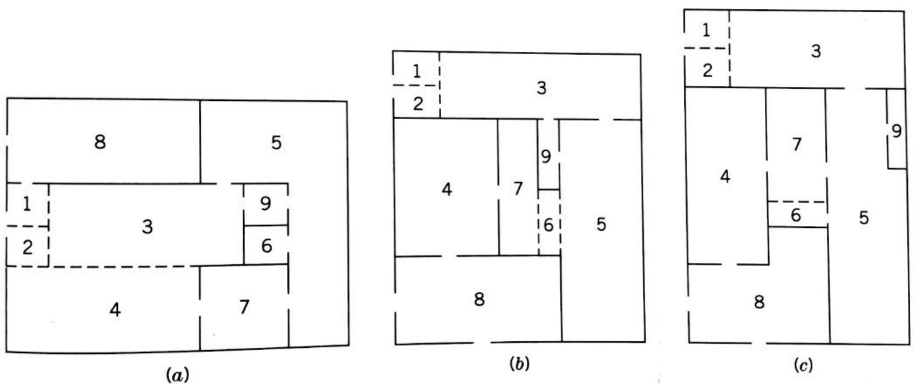


Figure 5 *Example of alternative block layouts (Tompkins, 2003)*

Step 10: Evaluation
The evaluation of all the alternative layouts is done. The pros and cons of each alternative layout are mentioned and compared. Basing on the results from evaluation, one final block layout can be selected. (Tompkins, 2003)

2.4 Systematic Handling Analysis

Systematic handling analysis is similar like Systematic Layout planning which was proposed by Richard Muther, where it consists of four phases, such as external integration plan, next overall handling plan, next step of detailed planning phase and last step is installation (Omar, 2011).

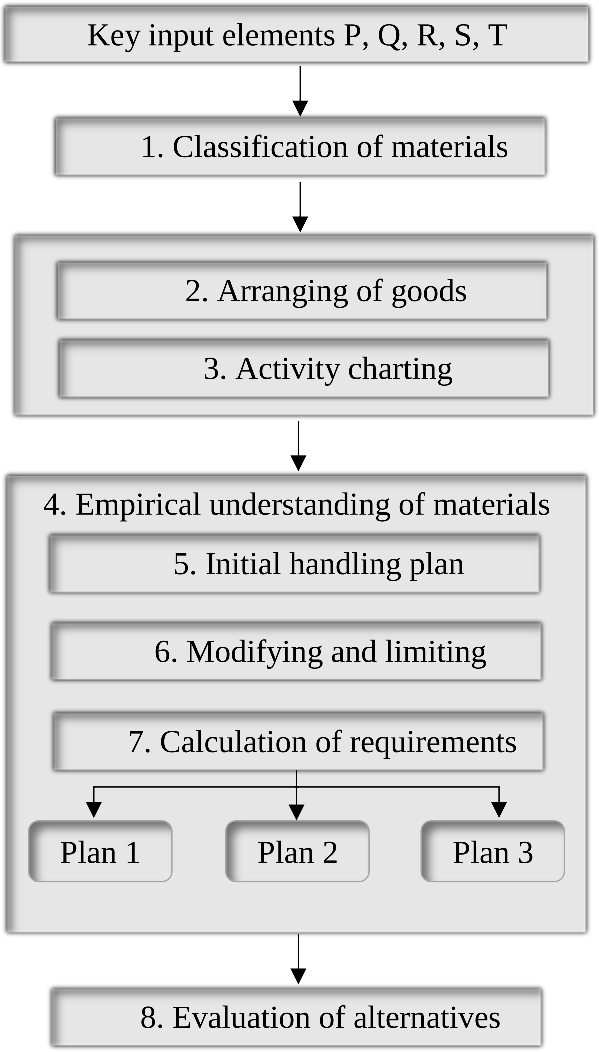


***Figure 6** SHA Flow (Li, 2010)*

Phase 1: External Integration: The movement of incoming and outgoing goods are studied. This phase is correlated with the inbound and outbound logistics.

Phase 2: Overall Handling Plan: Material handling is taken into consideration. This includes the material transport distance from once place to another as well as equipment that is used for transportation. In this phase, the decisions should be made according to the basic needs for material handling (Muther and Haganäs, 1969).

Phase 3: The Detailed Handling Plan: Material handling and transport distances within the specific area are analyzed. (Muther and Haganäs, 1969).

Phase 4: Installations: No plans are implemented until they are complete. After the plan is complete, the necessary steps are taken into consideration, such as implementation of physical handling facilities, procurement of equipment etc. (Muther and Haganäs, 1969).

The last step will not be taken into consideration in the analysis section, as the whole thesis is only the suggestion for the company.

In SHA there are five key elements that influence the material handling analysis. They include factors P, Q, R, S, T, described below (Muther and Haganäs, 1969).

Product (P): What type of product is transported. There might be different transport requirements for certain type of products.

Quantity (Q): The volume or number of goods that are moved from one point to another. The higher volume, the lower cost per unit load.

Routing (R): The route in which the goods flow. It is worth mentioning that there is always an initial moving cost, by which there are various costs for different routes for goods transportation.

Support Services (S): This element includes aspects like personnel, equipment and any support that is required for the movement of goods.

Time (T): Time that is taken for transportation and frequency of goods movement within the particular time.

All phases and key elements mentioned above lead to the Systematic Handling Analysis which can be divided into Material Analysis, Activity Analysis, and Modulus Analysis.

Material Analysis

The categorization of materials is based on material movements. There are two factors that are considered. Thirst one is material running, which includes physical and chemical properties of material that are transported. The other factor is logistical effects, which reflects on process, quality, equipment etc. (Li, 2010).

To visualize the material characteristics that should be analyzed, it is needed to relate to the empirical findings of material according to its specification. The steps followed in order to find empirical data are (Li, 2010):

- Mark all the goods in groups according to its similar specification or operations.
- The physical, chemical and other attributes must be recorded.
- Analyze the characteristics, to find the leading and decisive ones.
- Create a detailed visualized table for material analysis.

Activities analysis

To analyze the material handling processes, the of the material flow has to be examined first (Li, 2010). The analysis includes material classes, starting and ending point of the goods transportation, and route that material is handled (Muther and Haganäs, 1969).

For instance, there are two different methods that are used for activity analysis. First one is flowing analysis, used for single and very small varieties of products (Li, 2010). The whole process of the material flow has to be followed and recorded. The second one is From- To point analysis. If there is less categories of material, the material flow route is targeted and data is recorded.

Modus Analysis

This particular phase is a combination of various handling modules. This consists of the modules, such as initial handling analysis, limiting and modifying, calculating and evaluation (Li, 2010).

- Initial Handling Analysis

During this analysis the original data like material product, route, distance, current facility layout, equipment that is used for transportation is gathered (Li, 2010). The initial handling options should be in correlation with the collected original data. Any improvement techniques or further considerations should be based on the requirements of the studied case.

- Limiting and Modifying

In this section, it is very important to check the initial handling plan considering the practical issues. Apart from the key factors (P, Q, R, S, T), the other factors like human errors, efficiency of the equipment and possible limitation of the material handling. The issues that can be part of limiting and modifying module are mentioned below (Li, 2010).

- The plan which can influence the external operation.
- The plan has to satisfy the present and expected future requirements.
- The area and space can be limited.
- Present structure or other factors that cannot be modified.
- The cost limitation.
- Human factor which is limited to less staff.
- The warehouse or any management system limitations.

- Calculating and evaluating

This step supports initial handling plan by the calculating the demand of handling equipment and the capital investment (Li, 2010).

The evaluation module can be further divided into two types. One, comparing the financial factors, considering the facts like capital investment, material cost, managing cost of human resources, maintenance cost etc. Secondly, comparison is made on intangible factors. The evaluation is made by weighing factors based on advantage-disadvantage method. The main intangible factors are:

- The relationship between different operations on the shop floor.
- Suitable material handling way.
- The active limitation in expansion of the present layout.
- Constraints from different aspects like safety and security.
- User friendly maintenance and management tool.
- Correlation with other processes in the warehouse.
- The possible way of reducing travel distances without disturbing the process and operations.

After the evaluation, initial handling plan must be extended in detailed process and detailed material handling of goods in working unit. In fact, there are many more practical limitation, which could be a barrier for planning (Li, 2010).

2.5 Merger of warehouses

The experience shows that the merger of two separate industrial plants can be harder and more time and cost consuming than planning the entirely new warehouse (Stone, 2013). However, it is rare to start from the scratch in times of cost cutting and focus on goods consolidation. Stone (2013) believes that the most important aspect in terms of merger is an open communication and good planning. He mentions also some issues that people usually encounter while planning warehouse merger.

One of the pitfalls is inadequate space planning. People might not realize how much space each operation requires. It may happen that work cells, machinery or storage areas demand more space in the new facility. It should not be assumed that one operation will take the same amount of square meters in the previous and new warehouse. It might be the case that the current available space is not sufficient. It should be taken into consideration that the material flow will increase which leads to the higher utilization of space. Therefore, it is of high importance to create the layout plan before making major steps in rearranging two separate operations into one. Properly planned space utilization decreases the costs and prevent from creating dysfunctional warehouse (Stone, 2013).

Apart from the physical changes, warehouse merger involves also soft issues like management solutions or personnel. Moving one’s operations into others’ facility means adapting only one of the two systems since it is easier than inventing the completely new way to do things. Over the time, the management systems might evolve into something which is not possible to do from the day one after the merger (Stone, 2013). Another issue that many face while merging operations is ignoring personnel. The natural reaction from workers’ side is to fear from losing job after the merger. Therefore, it is very important to comfort them that the case does not have to lead to the personnel reduction. The reason behind consolidation should be communicated with staff. They should also have the right to express their opinion about the upcoming changes in order to feel involved and willing to adjust to new scenario (Schein, 1999).

3. Methodology

This chapter describes the research methodology that was implemented in the project in order to achieve its aim. The work process is illustrated which covers aspects like research approach and data collection. At last, the validity and reliability of the research are assessed.

3.1 Research Approach

A research strategy is the base for collecting, presenting, and analyzing data. There are many research strategies that differ depending on the requirements that the certain research has. Yin (2003) mentions five main research strategies: experiment, survey, archival analysis, history, and case study. Since the thesis concerns the case of Agility and Amring and aims to define the features answering the research questions, the case study design can be employed. It allows to retain the holistic characteristics of real-life events such as organizational processes (Yin, 2003).

Additionally, this case study employs the abductive research approach. It constitutes the combination of deduction and induction. The deductive approach views the theory first which is the foundation for the creation of hypothesis. Further, basing on the hypothesis, the data collection can be performed. Data collection, in turn, leads to the confirmation or rejection of the hypothesis. On the other hand, inductive approach focuses on the observations that are basis for the data collection. Next, data is analyzed which leads to the theory creation. Whereas, the abductive approach starts with the examination of the theory and initiates the method which leads to the certain results. The findings of the research are analyzed and compared with the theory (Kovács and Spens, 2005).

The goal of the researchers is to confront the theory with the empirical findings. The linear process consisting of certain research stages does not allow to use the potential advantages of the case research. Thus, the systematic combining of the theoretical framework, case and empirical world has to be implemented. The researchers have to go "back and forth" from theory to empirical observations in order to obtain the holistic understanding of the case (Dubois and Gadde, 2002).

What is more, the cross-sectional design was used which enables collecting data from more than one issue at the time. The research at Agility and Amring takes into consideration observations of different processes performed for numerous customers. The comparison of different processes facilitates the holistic view of warehouse operations in the investigated case. Consideration of various processes leads to the creation of the warehouse layout which includes different equipment, space requirements, human recourses, etc. The full understanding would not be possible if only one operation or process was considered (Yin, 2003).

3.2 Data Collection

For the following research, the data was collected by using various methods, like literature review, observations, and interviews. This thesis employs mixed of quantitative and qualitative approach in order to collect data and perform empirical study. Qualitative data is mostly used to gather information regarding current state of the case companies, their operations, and finally to create the processes flowchart. Whereas, the quantitative data was used to identify the space requirements and develop the warehouse layout. The secondary data is provided due to the open communication with managers in both Amring and Agility as well as access to the database and internal documentation.

Moreover, the case study is supported by the literature review which is performed at the beginning of the research in order to gather and understand the information relevant to the field of study. The literature review is performed in two stages. Firstly, the literature study was done in order to determine the suitable method to conduct the thesis as well as find out what data should be collected. Once the data is collected and Systematic Layout Planning implemented, the secondary literature study can be performed. The literature from the second study is supposed to give insight and ideas for the suggestions and recommendations for the company. Theory was collected from the articles and books available in the Chalmers Library and Google Books. The literature search is done by typing the keywords related to the layout design, layout planning procedure and warehouse space optimization.

Observation and shadowing are other methods used for the data collection. Those qualitative research techniques make the researchers observe the actual processes and employees in their daily routine and activities (McDonald, 2005). The advantage of observations and shadowing is the possibility of experiencing the reality of the warehouse operations. For the purpose of this thesis, the direct observations without participation of researchers were initiated (Yin, 2003). However, the researchers did not stay passive during observations. They kept open conversation with employees who gave explanations to the existing processes as the result of earlier initiated questions. These methods are very useful in terms of investigation the reality and understanding how the study should be performed later. Together with the first literature review, observations and shadowing helped to identify the need for Systematic Layout Planning, which will be described in the following section.

Lastly, the interviews are performed as data collection method. Yin (2003) describes various types of interviews depending on the desired outcome. One can list in-depth interview, formal interview and focused interview. This research uses individual in-depth interview (IDI). Apart from the fact that it might concern several events and provide the crucial information to the study, IDI provides the personal opinion of the interviewee (Yin, 2003). This aspect is very important in the studied case since the workers' experience and suggestions are crucial for the development of the new layout.

3.3 Research Process

Research starts from the defining the project scope. This can be achieved by the problem definition set by Agility during the first meetings at the company's site in Arendal. The scope was defined regarding to the directives given by the project supervisor at Agility. Further, the directives were discussed with the supervisor at Chalmers in order to meet the scientific relevance in the project. Researchers took into consideration problems stated by the case companies as well as the goals that both Agility and Amring aim to achieve. Problem and scope definition enabled framing the purpose of the study which led to the definition of the research questions. Created questions constitute the foundation for the thesis and should be answered in the research paper.

Next step in the working process was getting acquainted with the literature. The first theoretical study was performed in order to identify the method that should be implemented in the research as well as to find out what kind of data needs to be collected in order to implement the method successfully. During this stage, authors came across different methods for the layout planning. However, one method attracted their attention the most. After reviewing the work of one of the most specialized researchers in industrial engineering, Richard Muther, authors decided to implement Systematic Layout Planning (SLP) technique in this project. SLP, developed in 1961 (Liu et al., 2015), is practical and phased method for rearranging existing or designing new facilities which was the main reason to use it in the research. What is more, together with his associates, Muther created a range of step-by-step methods to recurring challenges and decisions in the plant layout and material handling in the industrial facilities. SLP approach can constitute the basis for other methods, such as Systematic Handling Analysis (SHA) (Richard Muther & Associates, 2016), which turned out to be useful and complementary in the following project. During the stage of literature review, the data collection process started. It involved mainly observations, internal documentation review, and open discussions with employees of different levels. The data collection is performed mostly at the beginning of the study, however, the additional information might be gathered at the later stage, if required.

The data collected as well as theoretical study were used for the analysis of the current state. The study of empirical findings is connected to the implementation of the Systematic Layout Planning that is the base for the designing of the layout. On this stage, the second literature study can be started in order to support the analysis and start looking for the answer to the research questions. Further, the analysis and SLP procedure lead to the creation of three alternative layouts which will be evaluated and discussed in the next stage. The most suitable solution will be chosen with the help of supervision from both university and company, literature review, and in-depth interviews as well. Later, the recommendations for Agility and Amring can be made to overcome the problems stated at the beginning of the case.

Every stage of the working process aims to get closer to answering the research questions and meeting the aim of the thesis. Fulfillment of all the stages would not be possible without theoretical background and support from the supervisors. The master thesis ends with the presentation of the achieved solution to both Agility and Chalmers University of Technology.

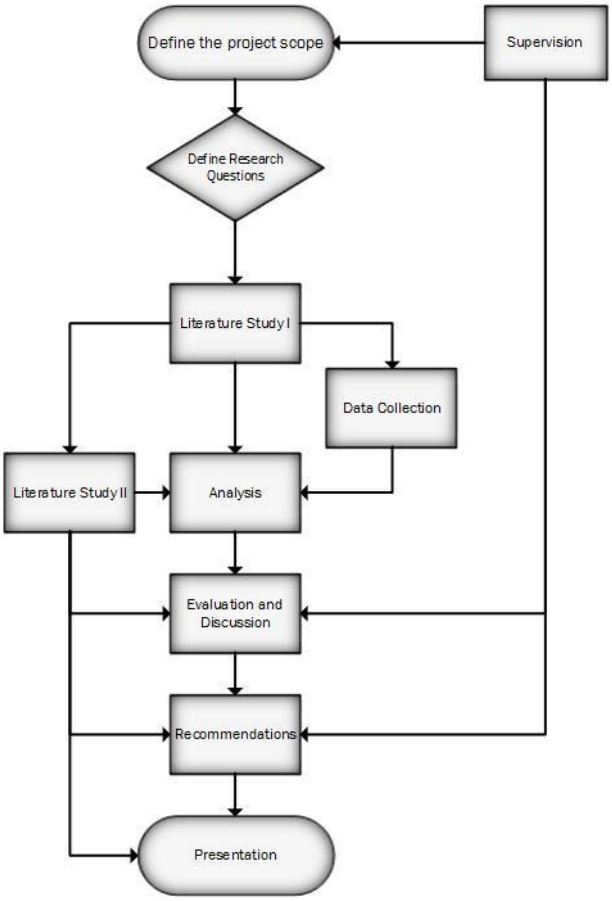


Figure 7 *Research Process*

3.4 Reliability and Validity of the study

According to Long and Johnson (2000), reliability seeks to provide differentiated data collection. The main purpose of reliability is to minimize errors in the research study. This concept concerns aspects like stability and equivalence. Stability examines if the data-collection measures provide fluctuation in the results over the time. Equivalence of the study can be provided by using alternative set of questions with the same meaning, or by observation by two researchers. While conducting the research, there is a possibility of influencing the result by personal opinion or drawing wrong conclusion by the researcher. Reliability challenges and reduces chances of such a situation (Kirk and Miller, 1986).

Long and Johnson (2000), simply refer to the validity as "the determination of whether a measurement instrument actually measures what it is supposed to measure" (Long and Johnson, 2000, p. 31). Validity can be divides into internal and external. The first one testes the match between theory and empirical data. External validity examines if the study findings can be generalized and used in different contexts.

The reliability and validity of the following study can be evaluated basing on the above references. The reliability might have been increased by the fact of having two researchers conducting the study. The risk of influencing study findings by personal convictions or bias is minimized in this case. Both researchers were present during observations and interviews at all occasions which ensures the equivalence. Moreover, thanks to the semi-structured character of the interviews and open communication with subjects of the study, all uncertainties could be clarified.

Due to the fact that no knowledge can be taken for granted (Long and Johnson, 2000), it is of high importance to use various sources to ensure the certainty of information. In this study, researchers validated results by using various sources and approaches of data collection. The robustness of the study is increased by using mix of qualitative and quantitative approach. Lastly, the method used in the research leads to findings that can be generalized, which increases the validity.

4. Empirical Findings

This chapter is divided into two sections describing each case company respectively. Each section starts with the description of the company and its function. Next, the customers, operations and current flow are presented. The section is concluded with the outline of the current layouts and space requirements.

4.1 Case company – Agility

Agility is one of the world's largest integrated logistics providers with more than 20 000 employees worldwide and operations in approximately 100 countries. It acquired more than 40 logistics brands around the world, investing billions to build a global network with a strong footprint in emerging markets (Agility, 2015). In Sweden, company operates in 6 cities, including Gothenburg. Currently, the distribution center that is located in Arendal employs 25 people and serves 19 different customers within 10,000 Sq. m warehouse. The main activities of the company concern warehousing but also repacking, pick and pack, software updating for navigation systems, and cross docking.

4.1.1 Company's function

Agility holds many functions as the third- party logistics supplier. It is responsible for serving various customers, which number reaches 19 at the moment. The customers expect to optimize their supply chain by leaving some of the functions to Agility. Therefore, in order to be competitive in 3PL market, the company is obliged to offer as many services as possible. The main operations that are offered by the company refer to the warehousing and distribution, repacking, pick and pack, cross-docking, customs clearance, software updating for cars, and control tower for logistics projects. It offers also so-called clean room, dedicated mostly for the repacking of goods that require clean environment. Most of the activities are driven by the demand. This means that Agility might add new services if the potential customers require so.

Figure 8 *Demand for Agility's services*

The demand for each service is depicted in the Figure 8 above and is presented as a percentage of all customers, out of 19, that use particular service. It should be noticed that only services that take place inside the warehouse walls were taken into consideration while creating the statistics. Therefore, control tower or customs clearance are not presented. The biggest and the most desired function is warehousing. Up to 65% of the current customers buy warehousing services. It is followed by 42% of customers that require repacking. The least popular services are software updating and usage of the clean room since they are bought only by one customer respectively.

4.1.2 Current Flow Description

This section presents the processes that take place in the current facility of Agility. Most of the time, goods are placed in the inventory before being redirected to the particular operation. The exception might be cross-docking and software updating. However, before that all the goods are unloaded from the truck and put to the buffer area where the process of receiving takes place. All received pallets are checked with the delivery list. Later on, the WMS generates the in-house label with the unique barcode which contains the information about goods, their quantity, supplier and the end customer. Despite the fact that each pallet has been already labelled by the supplier, the new labels have to be printed in order to minimize the information included in the barcode and to be recognized by Agility's WMS. This activity is usually performed by two workers, however, it might happen that one person is responsible for receiving the goods.

After the goods are received, all pallets are transported to the storage. Most of the time, they would be allocated randomly in the shelves. The newly printed label is scanned together with the shelf number (saved in the barcode) so that the system remembers the location of particular pallet. There is no clear information about the services that the particular pallet will be subjected to. That is why, the goods cannot be placed close to the dedicated service area. What is more, the WMS does not support goods classification which ´prevents from goods segregation, according to their turnover. However, more experienced employees recognize the consignments by the customer's name and try to place the received goods next to the area where they will be used next.

Further, the order message is generated and goods are relocated according to the information stated in the order. The message is given by the production leader and can be screened and followed on the tablet attached to every forklift in the warehouse. Workers can check which item should be moved from which location to which. The new location should be registered in the system.

After the goods are subjected to the certain operation, e.g. repacking, in most cases they are transported to the shipping area where they are waiting to be loaded on the truck and sent to the customer. Sometimes, it might happen that goods go back to the inventory where they are stored until the transport order is generated by the customer. See Figure 9 for the better understanding of Agility's current material flow.

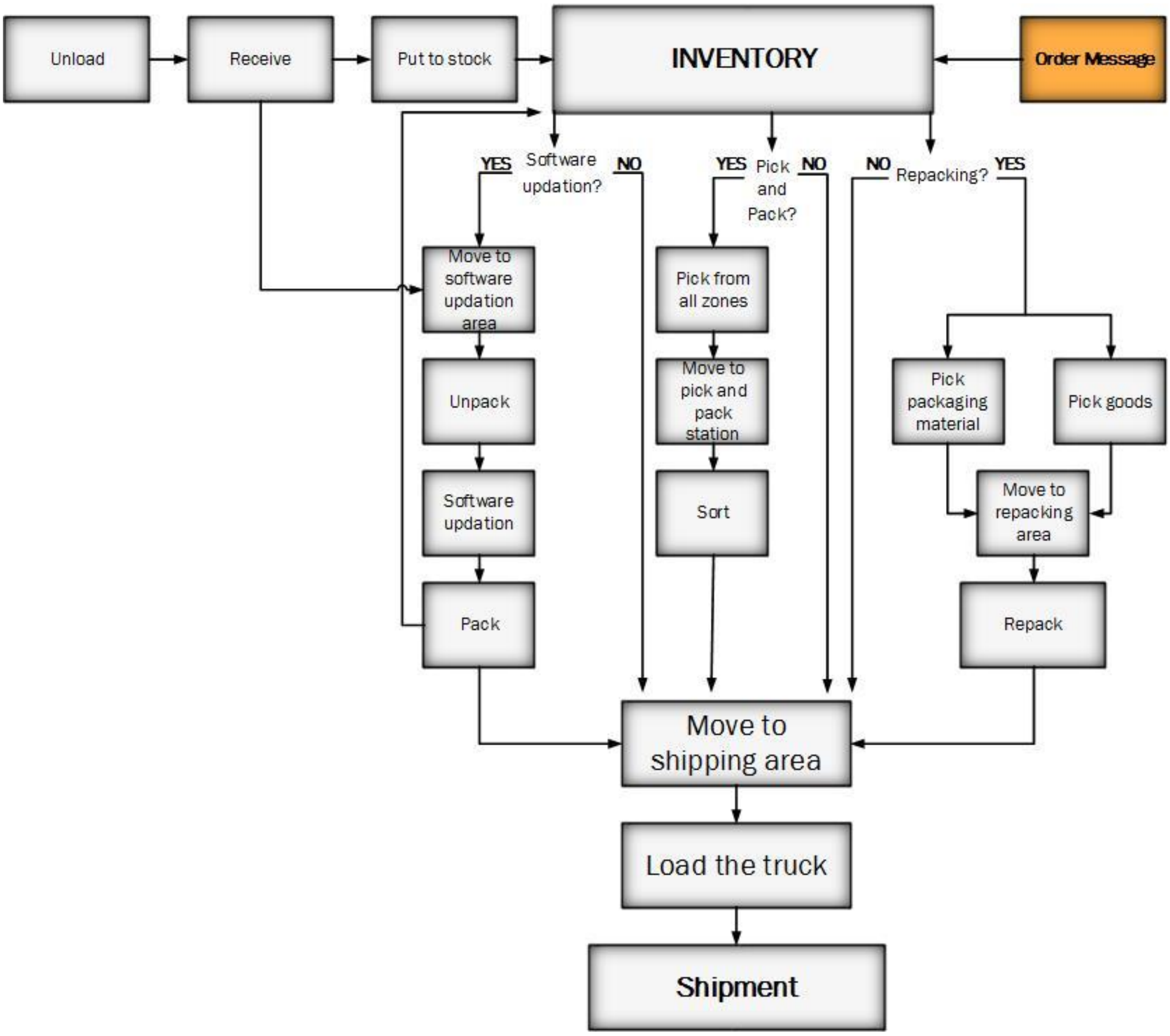


Figure 9 *Current Agility's material flow*

4.1.3 Goods handling

The movement of goods within the warehouse facility is based on few factors. The most important is demand for certain services from customers' end. In addition to the percentage summary of service demand presented in section 4.1.1, Table 1 presents more detailed information regarding customer's needs. Apart from the services offered at the small production areas within the warehouse, some customers require unusual way of loading goods into the truck. At the moment, the number of customers that ask for side loading is five out of nineteen.

Most of the goods are stored and transported on the standard EU pallets with dimensions of 80cm x 120cm, however, due to the collaboration with Asian suppliers, some cargo is moved with a help of sea pallets, which dimensions may vary from 100cm x 100cm to 120cm x 120cm. While collecting data, the summary of number of pallets owned by each customer respectively was made. For the need of project, every pallet unit of different kind, was converted into the number of pallet positions according to EU standards (Table1). The overall number of EU pallet positions that Agility has in stock is equal to 10225.

After the consultation with the financial manager, the rough estimation of the pallets movement was prepared. The given data is simplified and based on the monthly invoices that Agility sends to each customer. Only 12 customers out of 19 were taken into consideration while they have the most significance to the business. The number that is shown in the column "pallets movement/month" indicates number of pallets that come in to the warehouse and come out from the warehouse. For example, Agility receives only 400 pallets for Customer A each month, which are stored, and repacked. Therefore, another 400 pallets leave warehouse every month. Notice that all numbers are estimated and do not consider special cases of handling goods.

	Repacking Machine	Repacking Manual	Pick & Pack	Updating	Wareousing	EU Pallets position	Pallets movements/ month	Turnover
Customer A		50%	20%		30%	2500	800	4
Customer B			100%			300	1000	40
Customer C					100%	450	700	19
Customer D					100%	300	300	12
Customer E		5%			95%	150	150	12
Customer F	75%		10%		15%	1100	1200	13
Customer G	85%				15%	675	600	16
Customer H	95%				5%	2100	1150	10
Customer I	95%				5%	2100	500	4
Customer J	60%		1%		39%	450	3600	96
Customer K			90%		10%	100	250	30
Customer L				100%			3-4times/year	4
						10225		

Table 1 *Agility's inventory statement*

Lastly, the inventory statement presents the annually goods turnover based on the yearly pallets movement. The turnover shows how many times in the year, the stock belonging to the particular customer as changed completely. The numbers vary from 4 times up to 96 times per year, indicating slow and fast moving items.

4.1.4 Current Layout Description

Current warehouse of Agility, situated in Arendal, has the area of 8350m^2 with the ceiling height 7,3m. The major part of the facility is dedicated to the storage area that is divided into five-level selective pallet racking with the aisle width 3,1m. The storage capacity of the racking system, in the current configuration, is equal to approximately 8500 EU pallet positions. In 2014, company was lacking the space for the software updating operations required from the new customer. Therefore, Agility decided to invest in a mezzanine floor situated on the left end of the building. The mezzanine has dimensions 50m x 15m, which gives a total of 750m^2, of which half is not used at the moment. Under the mezzanine, the heavy repacking takes place. The area is equipped in the three stations conveyor belt with the packing robot at the end. Close to the heavy repacking, the side loading takes place. The loading takes place outside the building walls, on the ramp attached to it. However, goods prepared for the shipment are stored inside the building, close to the gate. Going further, next to the side loading the stations for charging the forklifts is situated. Behind, one can find the clean room, which is currently used for the manual repacking of products that do not need especially clean environment.

At the gates 1-4 the unloading takes place, whereas at the gates 5-7 the standard loading is done. Gates 8 and 9 are barely used. In front of them, on the floor, unclear customs goods are stored.

Behind the “customs” area, the small space is dedicated for the pick and pack operations. The area is equipped with one long table with computer and 18m long and 2m high shelves for the small spare parts.

See Appendix A for the Agility’s warehouse design. Note that the layout plan provided by the company is not updated by the recent changes that took place in year 2014. Therefore, some updated were made by the authors after the company visit.

Space requirements

After the interview with the Warehouse Manager, the estimation of required space for each operation was made. It was agreed that Agility will need approximately 8000m^2, as it is today, taking the advantage of the higher ceiling in the new facility (see the following section about Amring). Focusing on the most important functions of the company’s activity, the percentage relation of the department was prepared (Figure 10). Agility expects to remain the given ratio but to gain more space by rearranging operations.

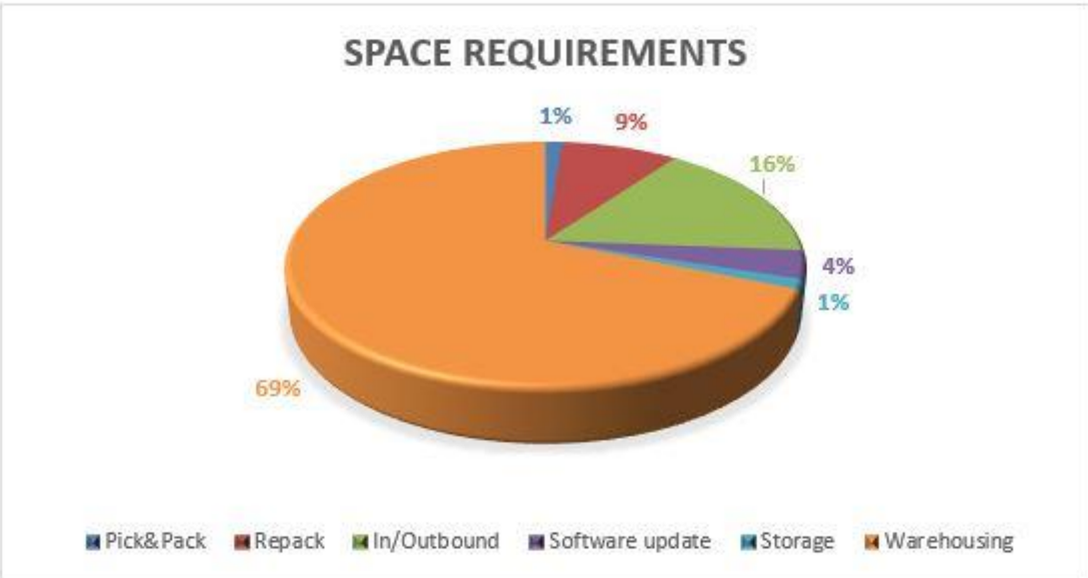


Figure 10 *Percentage space requirements for Agility’s operations*

4.1.5 Problem Identification

Company faces problems with the insufficient warehousing capacity. As a result, Agility has to rent around 1200 pallet places from the neighbor company, which costs money and brings management difficulties. It also causes additional goods handling. Since company holds function of the third party logistics, more activities than only warehousing are performed. It is connected to the variety of customer services and goods that might differ from year to year. If Agility gains new customer which requires repacking services, it can face problems due to the lack of space. This kind of variation requires flexibility that is not present in the current warehouse layout and management. What is more, the warehouse layout and racking system are not constructed in such a way to accommodate different types of packaging. Theoretically, there is no available storage space, however, the empty places on the racks might be noticed. It is only due to the fact that bigger consignment could not fit. What is more, the company does not use goods classification due to the limitations of current WMS. Therefore, goods allocation is done randomly in the warehouse and is followed by scanning the designated place.

Not only is the warehousing problematic. Employees complain about lack of space for the repacking operations, both heavy and manual. The issue with the heavy repacking is caused mostly because of the limited space under the mezzanine floor. During the interviews, staff pointed out the existence of the pillars that support the mezzanine that constitute a big obstacle. Moreover, the passage between repacking and warehouse racks is too narrow for the intensity of the movement that takes place there. If it comes to the manual repacking, the space is not sufficient neither. The operations take place in clean room which is too small and makes employees to move with the repacking to the aisles in the warehouse.

Therefore, Agility plans to move its warehouse and all operations to the premises of newly gained customer, Amring. The new facility has bigger potential in terms of space and safety as well as gives opportunity to redesign the layout of Agility in order to make it more efficient and optimize the space utilization.

4.2 Case company – Amring

Amring AB is a retail and wholesale company in the tire industry. It is owned by the family-owned Dutch company, PON, an international trading and service group with about 13,000 employees in 20 countries. In 2013 Amring AB moved into a new logistics center near the port of Gothenburg in Arendal. The total warehouse area in 20,000 Sq. m and gives employment to 76 people. (Amring AB, 2014) Amring AB is handling and distributing tires and rims to the Nordic market.

4.2.1 Company's function

Amring is a tire wholesale industry to Nordic region. It has own marketing and sales team to reach targets. According to the sales forecast the certain stock levels are maintained in the warehouse. The company's main function is to maintain the inventory according to its sales demand. Amring has various customers to whom it provides different services according to their requirements stated in the order. Apart from selling tires, Amring performs operations such as mounting the tires to rims or studding, where the tires are studded for winter (mainly operated during the seasonal change). The next activity is so-called pre-mounting, attaching the pressure gauge to the rims which is offered to the particular customer like HONDA. For this particular case the company acts like a third party logistics provider.

4.2.2 Current Flow Description

The detailed process of the company's material flow from inbound to outbound is presented in this section. As the ordered goods arrive to Amring, everything is transported to the inventory. The inventory acts a key factor in the process, because the goods are pulled from the inventory according to their customer orders. As the goods are unloaded from the truck, they are subjected to the cross check with the delivery list. All the goods which are received are scanned. New labels are created with unique serial number and warehouse locations are allotted according the goods specifications. At some situations the stock optimization and relocations are performed in the inventory.

As the order is created from the customer's end, the operations are initiated from the inventory. There are two different flows, depending on whether the mount is required or not. If the mount is required, then the clustering is performed. Different picks are performed from different locations. The operation requires pick kit, pick TPMS (pressure valves), pick rims, and pick tires from narrow aisles or from bulk storage. After the picking the TMPS and wheels, pre-mounting operation is performed. After this stage the wheels and tires are mounted in mounting stations. Then is repacked and sent to either to shipping dock or back to the inventory.

The detail process of the company inbounds to outbound is presented in this section. As the good arrive in at Amring, all the goods first goes to the inventory. The inventory acts a key factor in the process, as the studded tires, un-studded tires, rims and TPMS are stored in the inventory. After the orders message is created, the order is pulled from the inventory. As the goods are unloaded from the truck it is allowed in its buffer and cross checked with the delivery list. All the goods which are received are scanned, new labels are created with new serial number and locations are allotted according the goods specifications. At some situations the stock optimization and relocations are performed in the inventory.

As the order message, the operation is initiated from the inventory. There are two different flows, depending on whether the mount is required or not. If the mount is required then the clustering is performed, which different picks are performed from different locations. The operations include pick kit, pick TPMS (pressure valves), pick rims, and pick tires from narrow aisle or from bulk storage. After the picking operation, the TMPS are pre-mounted on wheels. After this stage the wheels and tires are mounted in mounting stations. Then it is packed and sent either to shipping area or placed back to the inventory.

If the mount is not required for the particular order, then the question arises if the order requires studded or un-studded tires for delivery. If the studded tires are required, then the inventory is checked for specified studded tire. If it is not available in the inventory, then the un-studded tires are picked from the inventory and it is studded manually in the production line using studding robots, followed by kitting. After the tires are studded either it is moved back to inventory or shipping area. If the un- studded tires are required, the tires or rims are pulled from the inventory and sent to shipping dock directly.

Outbound is the final stage of the process, before which goods that have to be delivered to the customers are stored in the buffer at shipping area.

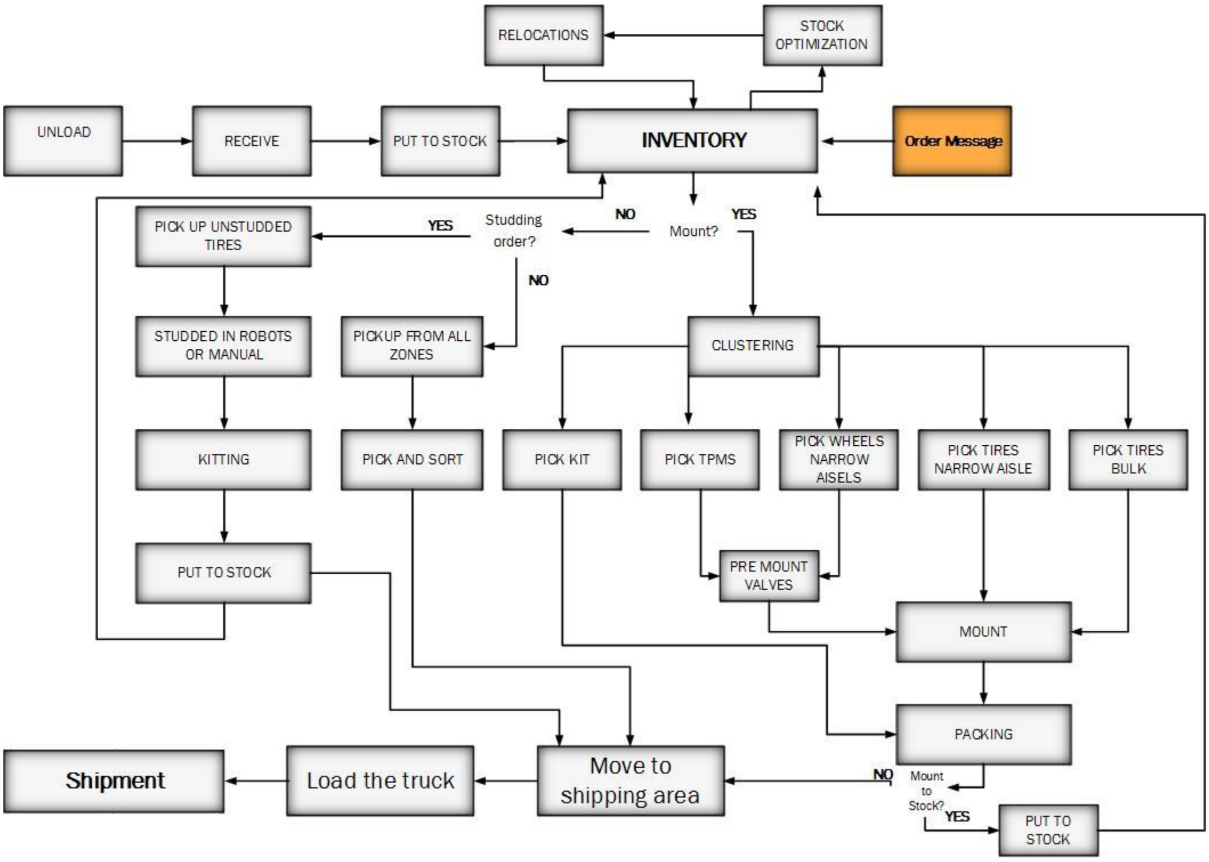


Figure 11*Current Amring's material flow*

4.2.3 Goods movement

The goods movements are mentioned here in different manner comparing to Agility. Amring has many different customers and different products that are in the inventory. After discussion with the Warehouse Manager the goods movements are calculated according to its operations which requires material flow from inventory to different operation location and have influence on the layout of the warehouse. The different operations are Mounting, Honda Put-away, Studding Picks, Studding Put-away.

Average stock level during one year of tires dedicated for mounting is 95000, in which 66500 are in bulk location and 28500 is from narrow aisle location. The stock level for wheels is 95000, always from single location narrow aisle wheels. The tires are stored at the desired location by using the cages, with 27 tires each. If the movements of tires occur, then the cages are moved to desired location.

Each year there is a total number of 3393 cage movements performed for mounting operation. From the bulk location it is 2375, and from narrow aisle location 1018 movements are performed to the mounting station. From NA wheels 3393 movements are made to mounting station. These movements are only to mounting station, from where it is sent directly to buffer in shipping area.

According to the material flow presented in the previous section some mounted products are transported to the shipping area, whereas the others go back to the inventory. The last case concerns Honda products. Therefore, Honda put-away was included in the table of goods movement to emphasize the material flow from mounting area to the inventory.

Every year 11000 tires are removed from the bulk area for mounting station and back to the inventory. After considering it in reference to cages, 2200 transactions are made to mounting station and back to inventory. So for each month 183 movements in total.

The operation of studding requires moving 50 000 tires from the inventory per year. In which 35000 tires are from bulk area and 15000 from narrow aisle location. So 1190 cage transactions are made in total for every year, which 883 from bulk and 357 from narrow aisle location. It makes 69 movements from bulk area and 30 movements from narrow aisle location to studding machines per month.

According to the material flow presented earlier, the studded tires from studding machine are always moved back to the inventory. In total 50000 tires are studded every year in which, 35000 tires and 15000 tires from studding machine location are moved to bulk and narrow aisle locations respectively. In other words, 883 cages are moved to bulk area and 357 cages to the narrow aisle every year. It gives 69 and 30 movements per month respectively.

		Tyre	Bulk tyre %	NA tyre %	NA whells
Mounting	Quantity	95 000	66500	28500	95000
	Transactions	3 393	2375	1018	3 393
	Per month	283	198	85	283
Honda putaway	Quantity	11 000	11000		
	Transactions	2 200	2 200		
	Per month	26 400	183		
Studding picks	Quantity	50 000	35000	15000	
	Transactions	1 190	833	357	
	Per month	99	69	30	
Studding putaway	Quantity	50 000	35000	15000	
	Transactions	1 190	833	357	
	Per month	99	69	30	

Figure 12 *Amring's goods movement*

4.2.4 Current Layout Description

The warehouse of Amring is situated in Arendal. The total area of warehouse is 24 000m^2 with ceiling height 9m and 4, 5 m. The major part of the warehouse is dedicated to storage area, which is divided into three major locations, such as bulk area, Narrow aisle area for tires and narrow aisle area for wheels. The retail area previously used for mounting the wheels to car, where two car lifts situated, but currently whole retail is not used for any operations. The marketing room and truck charging room is situated under the office floor. The marketing room is currently utilized for temporary storage of goods and some spare parts. The part of the space above the marketing room which is level of office space is currently unoccupied. The warehouse has ten gates in which gates 1-5 are used for inbound and 6-10 are used for outbound.

Some area is dedicated to spare parts storage which is located at right corner of the warehouse. And also warehouse has three production units, which are Pre- Mounting, Mounting and studding. The goods are stored in the cages as well as narrow aisle racks, which cannot be displaced due to the high cost of magnetic strip enabling turret truck to move.

In the current layout the TPMS station (pre-mounting) is located at right corner of the warehouse. The Mounting area is located next to TPMS station. The studding station consists of robots, which is located beside the mounting area. The entire production units are located near the out-bound gates of the warehouse.

Space requirements

After discussing with warehouse manager, the estimation for different operation are made accordingly from the total space given to Amring. According to the contract that was made between Amring and Agility, it stated that around 12000m^2 is allocated for complete operations of Amring. The space requirements are converted in to percentage, and indicated in pie chart below.

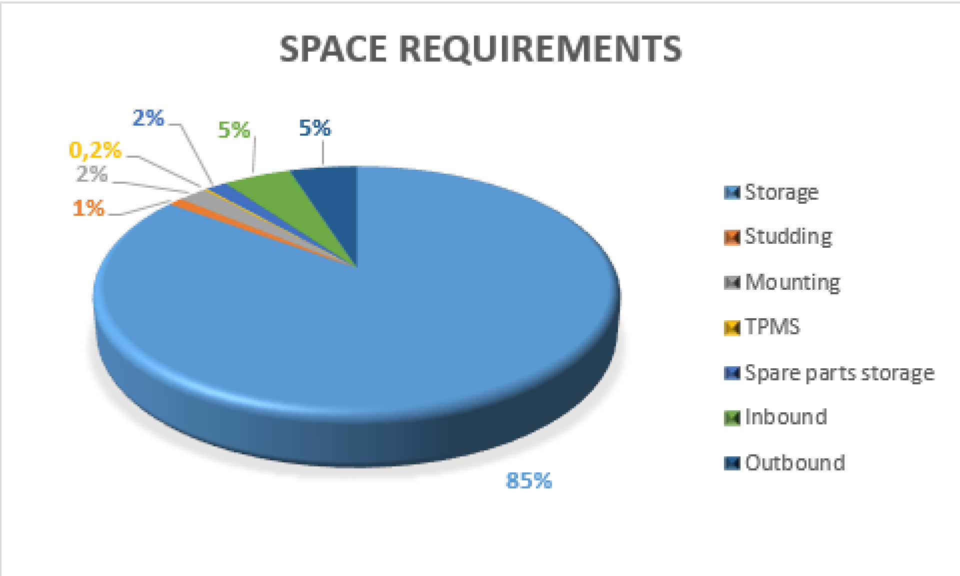


Figure 13 *Percentage space requirements for Amring's operations*

4.2.5 Problem Identification

Amring had a huge decline in sales and faced some loses in the past three years. For the current demand, the company does not require the entire warehouse space for its inventory purposes. In order to compete in the market, the company decided to merge with Agility.

The problem identified is that there is space in the warehouse, which is not used efficiently. As the entire production operations are situated at one end of the warehouse, the travel distances from the inventory are big. The ceiling height of the warehouse is not utilized properly.

In the current layout of the warehouse, the production units such as mounting area, TPMS, studding area are congested with heavy traffic flow at this area. The square meters that are allocated in current layout are insufficient for the current material flow in this area.

From the interview with the employees the information was gained that the spare parts storage is not allocated accordingly to the needs. Area allocated for spare parts is bigger than required. Moreover, spare parts racking is very high, which makes it difficult to reach the small spare parts. The lack of space is also noticeable in the area of temporary storage.

Above all, employees are not trained to perform all tasks which leads to the situation where colleagues with less workload cannot give support to the workers with higher workload.

5. Analysis

In this section, authors analyze collected data and follow the SLP steps in order to create alternative layout designs. Three alternatives are further assessed using SHA technique. The outline of Analysis Chapter is presented in Figure 14.

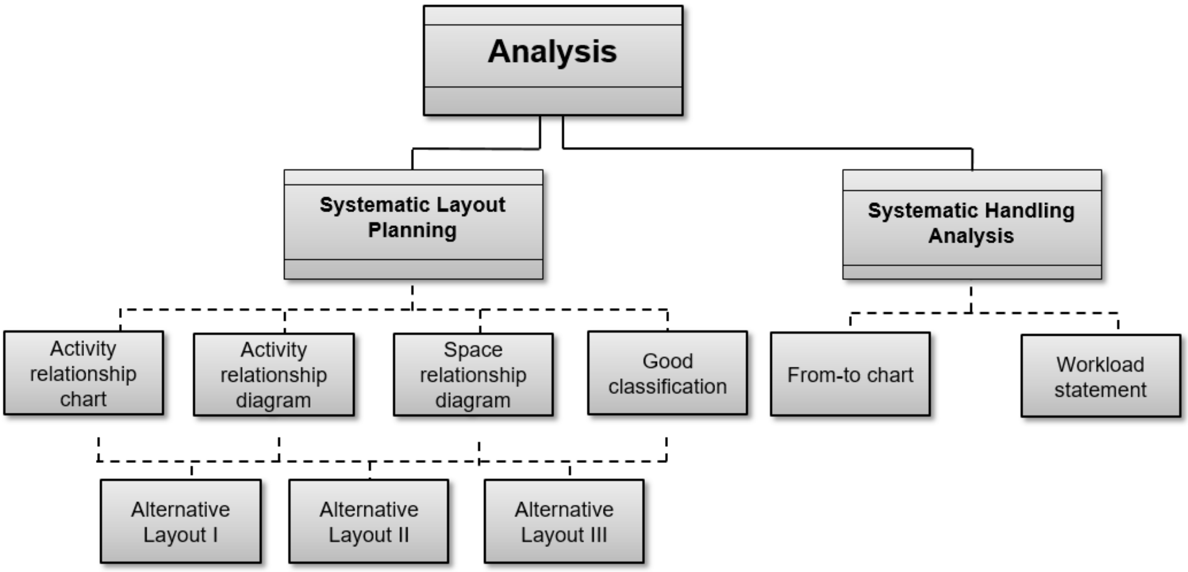


Figure 14 *Analysis outline*

5.1 Layout Design Analysis Based on SLP method

Combining two warehouses into one and creating an efficient layout plan requires investigation of both companies' activities. It also involves finding the correlation between each department in order to ensure smooth flow within warehouse walls as well as to avoid collisions and major obstacles. Presented analysis is based on the data collection and open communication with representatives of both companies. It is also supported by the literature review. Every step in the analysis process was discussed with both Amring and Agility in order to eliminate possible mistakes in the milestones of the project.

5.1.1 Activity relationship chart

After getting an idea of how the material flow looks like (see chapter 4), it is time to analyze the relationships between companies' departments. Authors listed the major operations and areas of both companies (Figure 15 and Figure 16) that have influence on how the facility might look like, but also on the material flow, space utilization and traffic.

The activity relationship chart shows the importance of closeness of each department/operation respectively. Intensity of material flow and frequency of usage were the major factors used for the assessment of the relationship relevance. Both indicators have the degree of low, medium and high, which were translated into numbers and used in the diagram accordingly. What is more, each relation was marked with the following letter: A, E, I, O, U, X which describe the importance of closeness form absolutely necessary to undesirable.

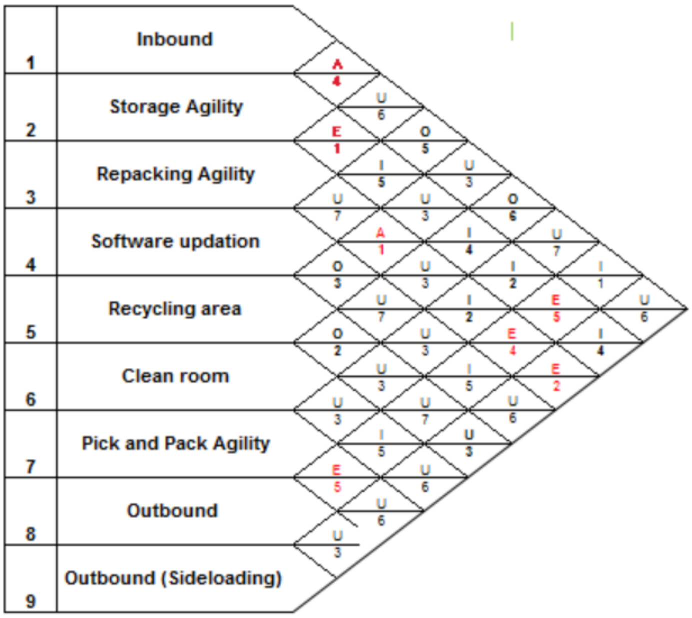


***Figure 16** Activity relationship chart Agility*

A	Absolutaly necessary
E	Especially important
I	Impoortant
O	Ordinary closeness
U	Unimportant
X	Undesirable

1	High frequency of use
2	Medium frequency of use
3	Low frequency of use
4	High material flow
5	Medium material flow
6	Low material flow
7	No relation

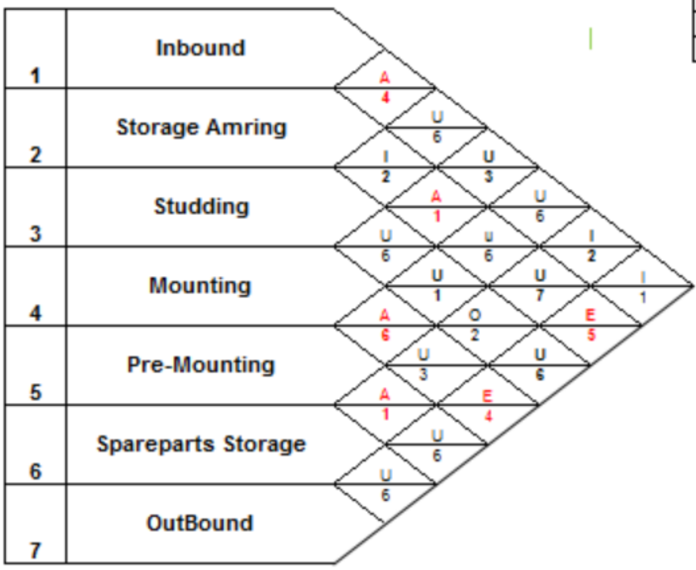


***Figure 15** Activity relationship chart Amring*

In Figure 17, the above charts were joined to show the relations between different departments of Agility and Amring after the merger. Note that the storage was presented as combined area of both companies in order to show that the companies might share the space according to the requirements. Later in the analysis, this area will be divided and described from the different angle depending on the allocation of each department in the new layout design. Following the Muther's method and previously prepared flow diagrams, the activity relationship chart was created. It is extremely important stage in the layout design process since it identifies the interfaces between warehouse operations and gives the first idea of how departments should be located.

After the analysis of the activity relationship chart, it is noticeable that some correlations require more attentions than others. The most important operations are marked in red color which indicates the absolutely or especially important closeness of two departments due to their high material flow or frequency of use. One example of high relevance could be relation between repacking Agility and recycling area due to the intense production of refuse material by the repacking operations.

Less important relationships were marked in blue color. Closeness between these departments is important or ordinarily important due to low material flow or frequency of use. For example, it is not necessary to locate spare parts storage close to studding area. The frequency of use of spare parts is relatively low due to the seasonality.

The activity relationship chart could be analyzed more deeply, however, the assumption of this project is to focus on the most important departments and relations. That is why, the following chart was simplified and redesigned to activity relationship diagram, presented in the next section.

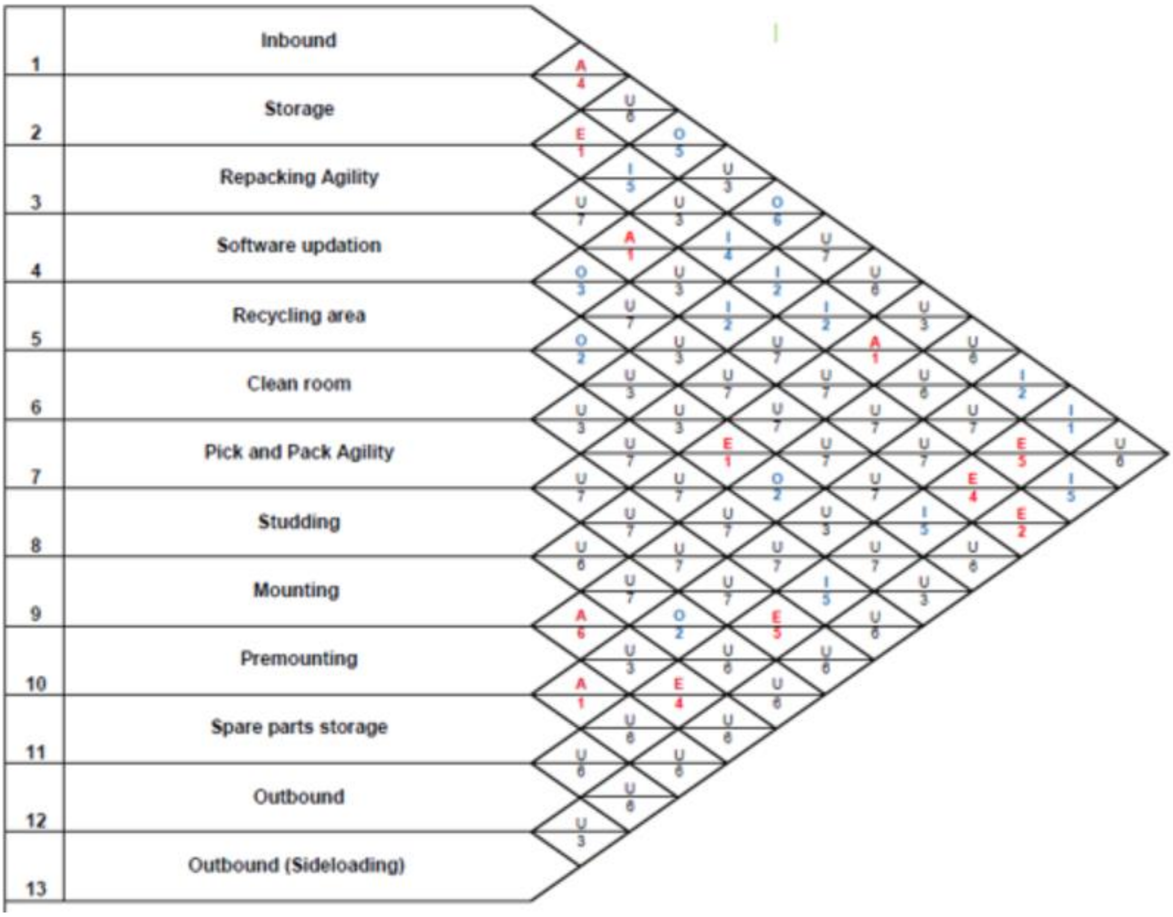


***Figure 17** Activity relationship chart*

5.1.2 Activity relationship diagram

After the analysis of the relationship between departments, it is time to present the results in a graphical form, introducing some simplifications. As mentioned before only the most crucial departments and operations were taken into consideration while creating the activity relationship diagram (Figure 18). The visualization of the correlations is the next step which goal is to minimize the number of overlapping lines, which in practice means less collisions and traffic inside the warehouse. The activity relationship diagram was constructed basing only on the data from the activity relationship chart that was presented in the previous section.

The numbers that are visible in the circles represent work units, which description can be found in the legend on the right side of the graph (Figure 18). Each circle was connected with one or more other circles showing that there is correlation between these departments. The importance of the closeness was marked with four different lines. Red solid line indicates absolute necessity for closeness, red dotted line means special importance, whereas blue solid and dotted lines depict important and ordinary closeness respectively.

It is already noticeable that Agility's and Amring's operations are mostly separated. On the left side of the diagram, its place found side loading, repacking, clean room, pick and pack, and software updating that are services offered by Agility. On the right side, Amring's operations are located, meaning studding spare parts storage, pre-mounting, and mounting. Shared areas are storage, inbound and outbound. The recycling area in the major obstacle in the presented diagram. It is needed by both companies since a lot of waste is created during repacking (Agility) and mounting (Amring). Currently, the closeness to the recycling area is in favor for Agility. The solution to this problem will be presented in the following sections.

It should be noted that the activity relationship diagram was drawn to get the proximity of the departments' relations. Thus, it is to help spotting issues that ought to be taken into consideration while designing the layout plan in the further steps.

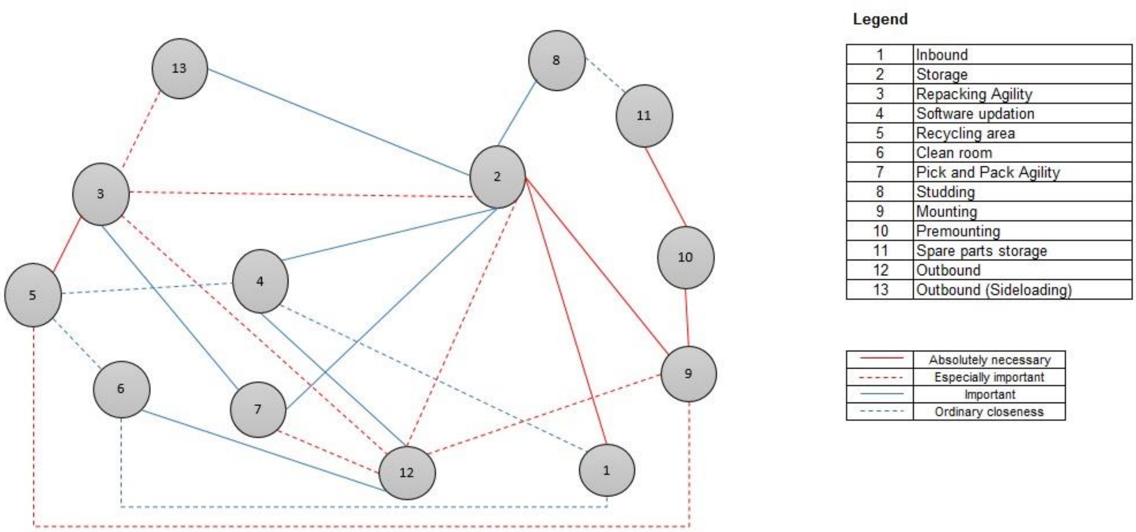


Figure 18 *Activity relationship diagram*

5.1.3 Space relationship diagram

Once the relationship between departments is established, it is important to check the space requirements of each operation. It might happen that the need for space in certain case will change the setting of the departments' allocation due to the area limitations of the facility.

After analyzing the data gathered while interviewing the companies' representatives, activity relationship diagram was simply transformed into the space relationship diagram (Figure 19).

Both figures look similar and show the correlation between work units. The difference is that the space requirement diagram provides with additional information of sufficient area for each operation.

It is visible that the majority of the available facility space, shall be occupied by the warehouse area, inbound and outbound operations, as well as repacking and mounting. From this point in analysis, the above mentioned departments will constitute the core factors and starting points in the creation of layout alternatives.

Note that the space requirements are given as an estimation and are based on the workers' experience. Thereby, numbers shown in the diagram below may slightly change depending on the walls location or rearrangement of the work stations.

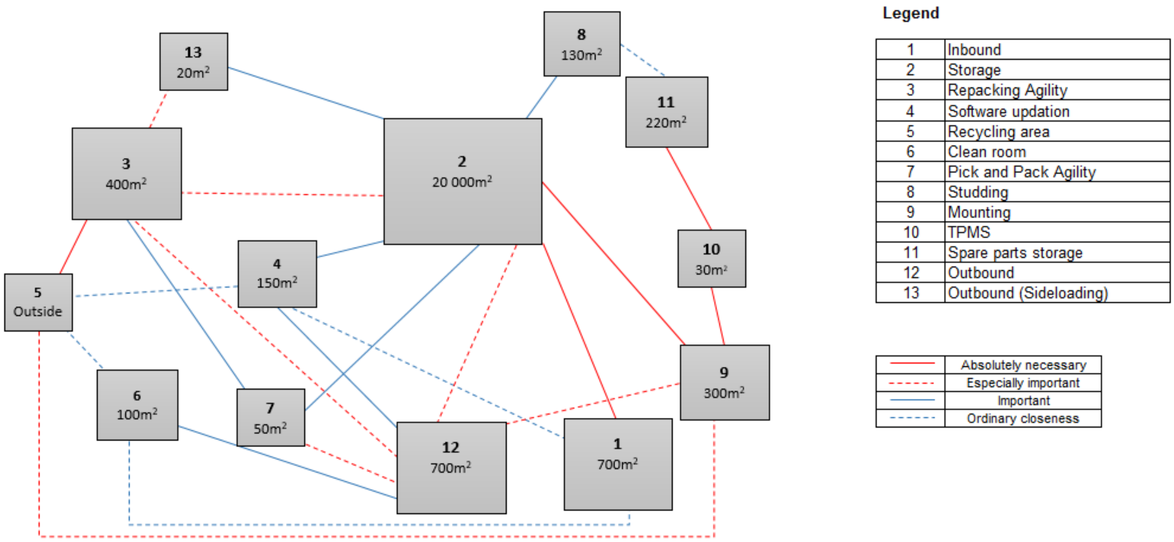


Figure 19 *Space relationship diagram*

5.2 Warehouse goods classification

Before proceeding with the creation of the layout alternatives, one step to the Muther's SLP technique has to be added at this point. In the previous stages the warehouse was mentioned as a one area to simplify the relationships analysis. However, it is important to divide warehouse into smaller areas, sections. The reason is that the location of goods has significant meaning in the 20 000m^2 warehouse. It mainly influences the transport distance from the operation site to the storage shelf as well as picking time.

The goods classification is two folded due to the difference in the companies' profiles. In case of Agility, the list of customers was given and the estimated service demand was provided. Basing on those two pieces of information, three product groups were created, which are warehousing, packaging, and pick and pack (Table 2). It means that customers C, D, E require mostly warehousing services. Whereas, customers B, K require pick and pack services, which means that their goods should be allocated close to the Pick and Pack area. It should be noted that customer L was not taken into consideration while creating the goods classification. It does not have big influence on the product flow due to the low turnover rate and it does not require warehousing.

Product groups		Turnover ABC Category		Fequency ABC Category		EU pallets
Name	*Customer*	*Category*	*Turnover*	*Category*	*Moves/month*	
Warehousing	Customer C	B	19	B	700	900
	Customer D	B	12	C	300	
	Customer E	B	12	C	150	
Packaging	Customer F	B	13	A	1200	8925
	Customer G	B	16	B	600	
	Customer H	C	10	A	1150	
	Customer I	C	4	C	500	
	Customer J	A	96	A	3600	
	Customer A	C	4	B	800	
Pick and Pack	Customer B	A	40	B	1000	400
	Customer K	B	30	C	250	

A	31<	**A**	1001<
B	11-30	**B**	501-1000
C	1-10	**C**	1-500

Table 2 *Goods classification- Agility*

Moreover, basing on the Pareto 80/20 rule, goods categories were created within each product group. Firstly, authors divided the goods according to the turnover rate. However, after further consideration the conclusion was drawn that the received data is irrelevant. It is because, the high turnover of goods does not necessarily mean the frequent goods movement within the warehouse and low turnover does not indicate rare goods transportation. In the layout design planning, the goods movement is the aspect that matters. That is why, the ABC categorization was prepared once again, basing on the frequency of pallets movement per month, provided by the Agility's representative. Customers marked with the A letter own goods of higher importance which make them necessary to be located close to the operations they are subjected to. C letter indicates lowest importance.

In addition to the categorization, the number of EU pallets included in each product group was stated in Table 2. Number of pallet positions is an important aspect to be taken into account while designing the layout. It helps to get an idea of how much space it is required for storage. It might lead to the answer for what kind of racking system should be use in order to fit the inventory, leave some space for the future growth as well as to utilize the available space as much as possible.

In case of Amring, the situation is a bit different. The categorization of goods according to the frequency of movement was not possible due to the huge amount of data and big variety of customers and products. The advantage here is that the Amring's WMS allows random goods allocation which increases the space utilization. Therefore, the only classification that was made is according to the type of stored goods and type of racking system. The categories mentioned are as follows: narrow aisle rims, narrow aisle tires, narrow aisle cages, bulk tires.

Warehouse goods classification will be clarified and visualized in the following section regarding alternative layouts.

5.3 Alternative Layouts

Knowing the material flows, activity and space relationships, warehouse goods classification as well as constraints, the actual layout design can be suggested. As it was mentioned before, it is important to provide a few alternatives of the layout in order to have the point of reference for comparison. According to the method proposed by Muther, the layout plans should be depicted in the form of block diagrams. In spite of this fact, authors decided to go one step forward and create the 3D design in the free version of Sketch Up software. While designing the logistics center, aspects like transport distances, efficient space utilization, and safety were main indicators.

The design has started from the drawing the borders of the facility according to the actual dimensions. The walls, doors and shipping docks were applied to the plan because it was unlikely for those elements to be removed from the layout. As mentioned before in the analysis, the allocation of different departments started from the core factors that are the most space consuming. Therefore, inbound and outbound area was drawn with the designated 1400m^2 jointly. Next, the storage area was depicted in the design. In the starting, 20000 m^2 was filled with the simple racking system that was reformed later according to the design requirements. Later, the retail area was arranged for the Agility's repacking operations, regarding the contract assumptions. It was given 1400 m^2, which was more than required, however, it assured the smooth flow around the repacking machine. The next element that was being allocated is Amring's mounting. Lastly, other smaller operations were located and the warehouse goods classification was included in the layout of the storage area. Depending on the number of goods in stock, the number of racks dedicated to certain customer was established.

5.3.1 Retail area

As the contract between merging parties stated that the retail area ought to be dedicated to Agility, it was the first place to be arranged with the necessary details. As it is depicted in the Figure 20, in order to gain as much space as possible, the middle wall was removed. The cost of which and construction restrictions were analyzed and approved by the members of both companies.

Figure 20 *Retail area design*

The repacking machine was situated in the end part of the room, close to the gates which can be utilized as the output for the recycling materials. What is more, there is enough space for the manual repacking which used to take place in the clean room. Now the clean room can be used for the purpose that it was meant to from the beginning. In order to use available space more efficiently, the standard racking system was suggested in the retail room. The ceiling height allows to have 3 levels racking system that can be used for temporary storage or repacked goods or packaging materials which can be handled with the counterbalanced forklift. Moreover, the design takes advantage of the additional two gates from which one of them can be used for the side loading. The activity relationship diagram showed that it is important to locate side loading close to the heavy repacking. Moreover, it is more convenient to perform this operation inside the facility and under the roof. The working conditions are improved which leads to the workers' satisfaction. Lastly, the remaining space close to the second gate can be utilized for the shipping area or temporary storage. The ceiling height should be also used by implementing small racks.

5.3.2 Alternative Layout I

The first layout alternative was inspired by two factors, the closeness of Amring operations to its storage and relative closeness to the Agility repacking operations, which are situated in previously unused retail area. All main activities of Amring were situated in the middle of the back wall of the facility, only 90m from the retail area. Close location of operations leads to the better workforce rotation. After a cross-training of employees, the workload can be distributed evenly.

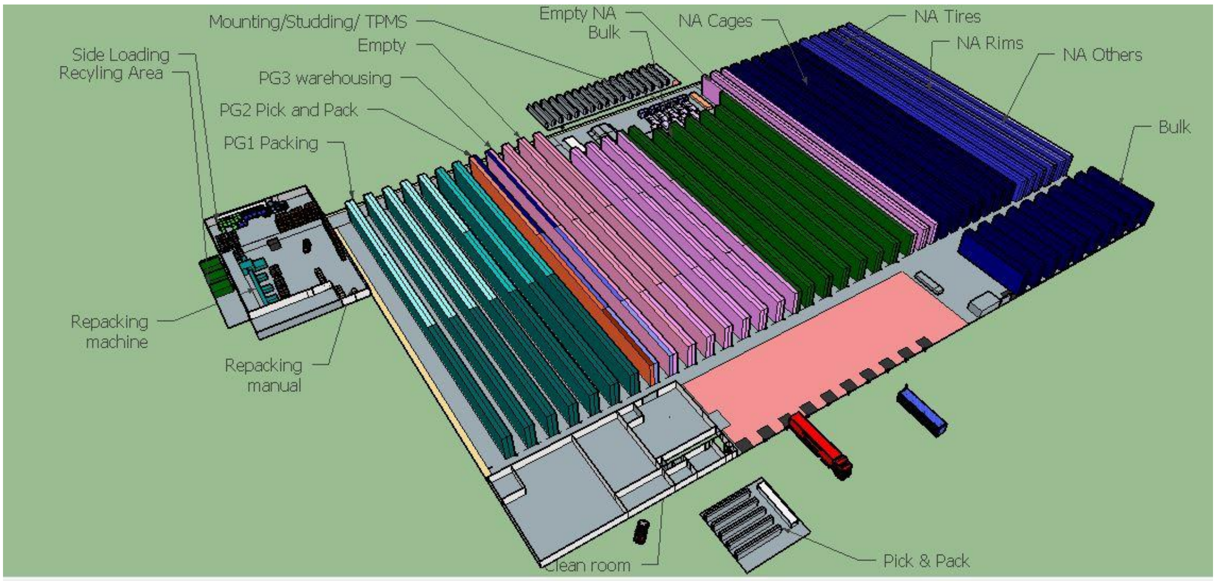


Figure 21 *Alternative Layout Plan I*

In order to use the ceiling height to the maximum, the mezzanine was suggested to be moved from the Agility's current premises. The dimensions of 50m x 15m of the mezzanine give the area of 1500m^2 from both levels jointly. It allows allocation of mounting, studding, TPMS station (pre-mounting) on the ground floor, and spare parts storage on the top floor. The placement of these areas can be seen in the Figure 22 below. Note that the middle columns that occupied significant space, which constituted the obstacle for the employees, can be removed without any construction consequences (according to the mezzanine producer).

The storage located upstairs allows usage of lower racks which, in turn, makes products more reachable by the staff. The goods collection does not require heavy trucks which makes the location even more attractive. What is more, the absolutely necessity of locating spare parts storage close to the pre-mounting is satisfied in this case. The goods flow from the upper floor to the TPMS station (yellow table) can be performed with a use of the spiral slide, marked in orange (Figure 22).

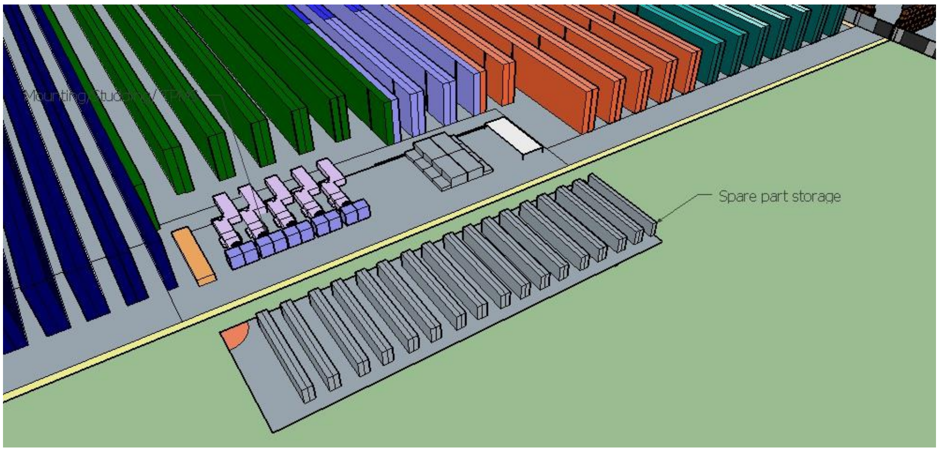


Figure 22 *Mezzanine Arrangements Layout I*

The obstacle in the mezzanine arrangements is that the mounting robots have to be located slightly outside the mezzanine in order to leave the sufficient way between the robots and the facility wall.

The clean room was allocated in the front part of the facility, close to the shipping docks. The space, previously used for the marketing room, gives approximately 241m^2 which is 141m^2 more that required for the clean room. That is why, the software updating operations could also take place in this location. The reason is that GPS software device requires clean environment which was not sufficient on the top of the mezzanine in the Agility's warehouse. On the top of the clean room, the authors identified the potential for unused space (See Figure 23). The area of 240m^2 is a good spot for the Pick & Pack operations of Agility. Again, the building height can be utilized more effectively. The 2m high racks, which are currently used for the small parts, can be moved from the Agility's logistics center in order to avoid extra costs.

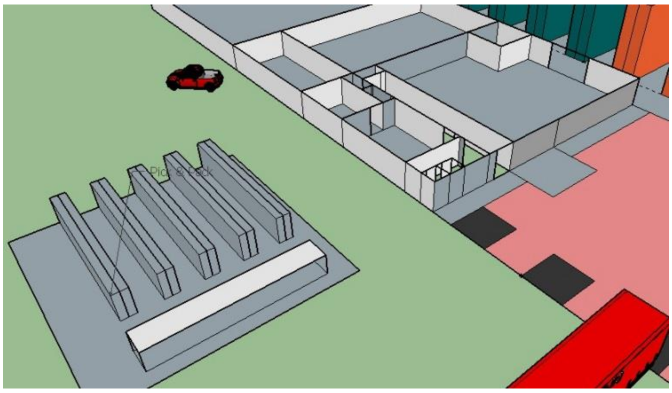


Figure 23 *Pick & Pack and Clean room allocation*

After situating all operations, the authors had a closer look at the goods allocation within the storage area. Figure 21 presents warehouse goods classification. Each product group is marked with the different color. The layout considers two types of racking system, narrow 1,8m aisle operated with the turret truck and standard 3,0m aisle dedicated for the tire bulks that are operated with either counterbalanced truck or reach truck as well as Agility's stock. Each rack is built of 6 levels pallets shelves. Whereas, each bulk raw has only 5 levels due to safety reasons and restrictions regarding the distance of rubber products from sprinklers. The width of the shelf is 2.5m which can fit three EU pallets or two sea pallets. Whereas, one bulk is 3,4m wide and cage 2,3m.

Looking from the left side of the layout plan I (Figure 21), the racks marked with the turquoise color are designated for the product group 'Packaging' which is located close to the repacking area. The approximate number of pallet positions in this storage area is 9000. Further, the 'turquoise' section was divided into ABC categories. Colors from lightest to darkest indicate the frequency of goods movement from A to C respectively. Orange racks are dedicated for the product group "Pick&Pack" situated close to the pick and pack area above the clean room. Lastly, the purple racks are for the product group "Warehousing". The category A for this group is situated close to the inbound and outbound area where the major flows of goods take place.

The pink area with racking system shows the possibility of gaining extra storage space that was obtained due to the higher ceiling in Amring's premises. However, for the comparison and better understanding of the significance of different racking systems, number of pallet positions in each case was calculated and presented in the Research Result section.

The green area is dedicated for the bulk filled with tires and can accommodate around 2300 load units. Since this amount is not sufficient for the inventory that Amring has, the additional bulk area was suggested in the bottom right corner of the layout. This area can fit around 760 bulks extra. The narrow aisles that were present in the Amring's premises from the beginning cannot be moved due to the high costs. Therefore, also the location of goods does not have to be changed. Planned decrease in the Amring's inventory level and additional bulk area leads to free space on four racks in the narrow aisle behind the green bulk area.

5.3.3 Alternative Layout II

Second layout alternative does not differ much from the previous one. All operations of Agility are located in the same places; repacking and side loading in the retail area, clean room,

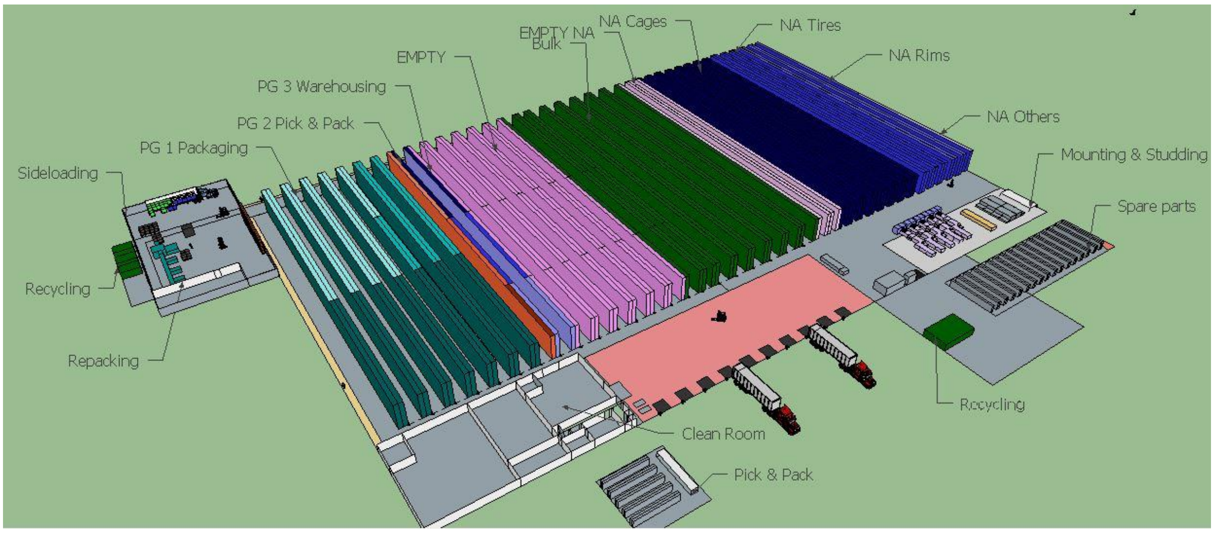


Figure 24 *Alternative Layout Plan II*

software updating inside the marketing room and pick and pack above it. The main difference is in the location of the Amring operations (Figure 24).

The configuration of the mezzanine is almost the same. Only mounting robots are situated in the opposite direction so that tires and rims can be picked up from the blue cages and the final, mounted product could go directly to the outbound area (see Figure 25). Since the recycling area is situated in the other side of the facility, the need for an additional waste bins arises. That is why, alternative layout plan II suggests locating one more recycling station outside the building, close to the mounting which generates a lot of wastes. The transport of production scrap would be performed through the additional gate that is located behind the shipping docks.

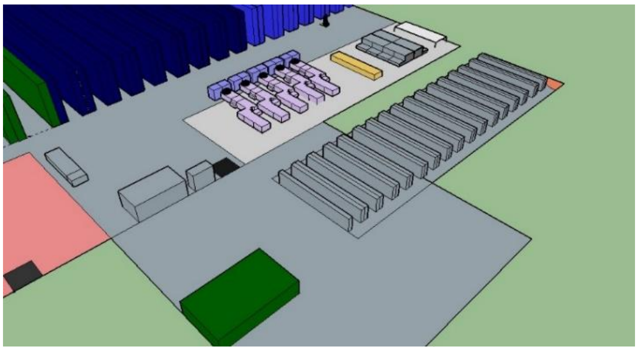


Figure 25 *Mezzanine arrangements Layout II*

If it comes to the storage arrangements, the classification of goods is done in the same manner due to the similar operations allocation. However, it is noticeable that this layout suggestion gives higher number of empty pallet locations in the aisles located in the Agility's part of the storage area, close to the bulks. Also, the green bulk area is enlarged in this scenario, however, the additional bulk area in the corner of the warehouse is replaced by the mezzanine floor.

5.3.4 Alternative Layout III

Third and final layout alternative was partially inspired by the Agility's suggestions. Again, repacking and side loading would take place in the retail area. Clean room and software

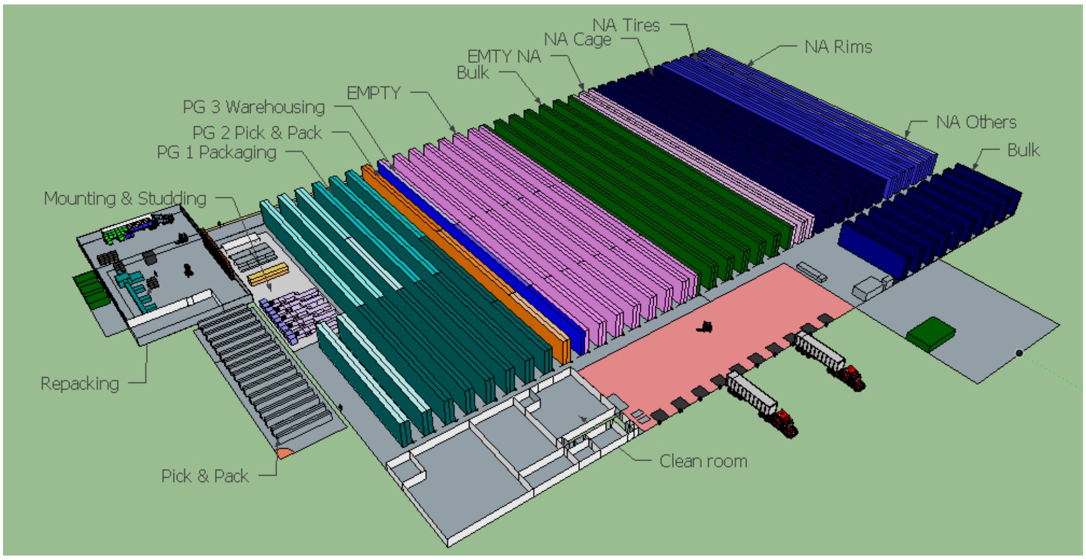


Figure 26 *Alternative Layout Plan III*

updating would be located in the marketing room. The space above it remains unutilized as it is today.

The mezzanine is still used for Amring’s mounting, studding and TPMS station. On the top of mezzanine floor, the spare parts storage could be located (see Figure 24), as it was proposed in the other two alternatives.

The other option could be, in this case, allocating pick and pack above the mezzanine and spare part storage in the racks situated close to the TPMS station. However, some of the space that could be dedicated for the repacking group of products would be occupied in this case. The third layout alternative includes also an extra bulk area and possible rearrangement of the mounting operations so that it fits under the mezzanine floor. An alternative way of putting mounting robots was derived from the fact of having less space for the aisle than in the other two cases. See Figure 27 for mezzanine arrangement.

Figure 27*Alternative mezzanine arrangement layout III*

5.4 Layout Design Analysis Based on SHA method

In this section the SLP approach will be complemented with the SHA method in order to lead to the comparison of the alternative layouts, presented in the previous section. The analysis concentrates mostly on the goods movements and travel distances.

5.4.1 Goods movements

Flow – To chart (Table 3) presented below indicates complete detailed list of movements in between the departments. The movements are based on the activity relationship chart, volume, and number of times the material flows between the related departments. The movements’ numbers mentioned are given monthly wise.

In the main column and row of the table, all the departments of both Agility and Amring are mentioned. To be noted that the list of customers indicates the goods group. The customers’ names are given in order to make the analysis easier while filling in the table with the number of movements.

For example, there is strong relation and material flow from inbound to each location. In case of Customer A, the total material movement is 800, which means that from inbound to outbound 800 movements. The movement unit means 1 for load unit, e.g. pallet, bulk or cage. The material flow from inbound to Customer A is around 400 times per month. We assume that same amount of goods flows in and out.

The movement that are made between the Customer A and repacking is about 200, as in the empirical findings it is found that only 50% of the total goods flow to repacking. And also it is found that 20% of goods (around 80 pallets) flows from warehouse to pick and pack area. And the amount of movements that is made only to outbound directly from the storage is around 120.

Second example, the Amring bulk tire. The amount of movements that is made from inbound to bulk tire location is around 228 times. The movements that are made by bulk tire to studding is 69, to mounting is 198 and to outbound is 30. The movements are that are found are explained in detail in empirical finding in company case of Amring.

	Repacking Machine	Repacking Manual	Pick & Pack	Studding	Mounting	Outbound	Sideloading	Customer A	Customer B	Customer C	Customer D	Customer E	Customer F	Customer G	Customer H	Customer I	Customer J	Customer K	Amring bulk tyre	Amring NA tyre	Amring NA wheels
1 Inbound	-	-	-	-	-	-	-	400	500	350	150	75	600	300	575	250	1800	125	228	115	283
2 Repacking Machine	-	-	-	-	-	-	2569	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3 Repacking Manual	-	-	-	-	-	204	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7 Pick & Pack	-	-	-	-	-	693	78	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8 Studding	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	69	30	-
9 Mounting	-	-	-	-	-	228	-	-	-	-	-	-	-	-	-	-	-	-	183	-	-
15 Customer A	-	200	80	-	-	120	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16 Customer B	-	-	500	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17 Customer C	-	-	-	-	-	350	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
18 Customer D	-	-	-	-	-	150	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19 Customer E	-	4	-	-	-	71	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20 Customer F	450	-	60	-	-	-	90	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21 Customer G	255	-	-	-	-	-	45	-	-	-	-	-	-	-	-	-	-	-	-	-	-
22 Customer H	546	-	-	-	-	-	29	-	-	-	-	-	-	-	-	-	-	-	-	-	-
23 Customer I	237	-	-	-	-	-	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24 Customer J	1080	-	180	-	-	-	702	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25 Customer K	-	-	112	-	-	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26 Customer L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27 Amring bulk tyre	-	-	-	69	198	252	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28 Amring NA tyre	-	-	-	30	85	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29 Amring NA wheels	-	-	-	-	283	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 3 *From-To Chart*

5.4.2 Travel Distances

The full statement of travel movements and distances can be found in the Table 4 that has been derived from From-To Chart, and completed by the input data. In this table there are four columns mentioned: Route, Alternative I, Alternative II, and Alternative III.

Route: In this column the data is copied from From-To chart and indicates the number of movements that are made between given locations. For Example, in second row, under route column 1-16 is mentioned and under movements column it is mentioned 500. This means that material is moved 500 times from location 1 to 16 on a monthly basis.

Alternative I, II, III: The suggested alternative layouts analysis is included under those columns. Under each alternative, distances and workloads are mentioned. The units that are measured from one location to another is called distance and is given in meters. For example, the distance between location 1 and15 is 105m in Alternative I.

Workloads are the units that indicate the total system handling. Here the workloads are calculated by the formula

$$\text{Workload (S)} = Fij*Dij,$$

where S stands for workload, Fij represents the material flow from location i to j, Dij indicates the length of the distance between i and j.

For Example, in the second row. From location 1 to15 there are 400 movements made. The distance that is calculated from location 1 to 15 in the Layout Alternative I is 105m. Therefore,

$$S= 400*105= 42000m.$$

After the calculation of the workloads from every from-to location, all the work loads are summed in the last row of the table. There will be three different total workloads for different options. The final result will be discussed in the following section.

Serial number	Route		Alternative I		Alternative II		Alternative III	
	From- To	*Movements*	*Distance I*	*Workloads I*	*Distance II*	*Workload II*	*Distance III*	*Workload III*
1	1-4	3-4 times						
2	1-15	400	105	42000	105	42000	105	42000
3	1-16	500	60	30000	60	30000	60	30000
4	1-17	350	90	31500	90	31500	90	31500
5	1-18	150	111	16650	111	16650	111	16650
6	1-19	75	111	8325	111	8325	111	8325
7	1-20	600	130	78000	130	78000	130	78000
8	1-21	300	108	32400	108	32400	108	32400
9	1-22	575	130	74750	130	74750	130	74750
10	1-23	250	85	21250	85	21250	85	21250
11	1-24	1800	130	234000	130	234000	130	234000
52	27-8	30	64	1920	114	3420	170	5100
53	27-9	198	61	12078	99	19602	180	35640
54	27-13	252	65	16380	65	16380	110	27720
55	28-8	30	118	3540	85	2550	225	6750
56	28-9	85	101	8585	63	5355	235	19975
57	28-13	30	97	2910	97	2910	150	4500
58	29-9	283	109	30847	88,00	24904	260	73580
SUM				**1379237**		**1377607**		**1655540**

Table 4 *Workload Statement*

6. Research Result

Obtained results of study are presented and the optimal solution is chosen in this chapter. The justification behind the decision is stated as well.

6.1 Comparison of alternative layouts

After analyzing the collected empirical data and confronting it with the literature review, the three alternative layout designs were suggested. The travel time and distance as well as the pallet locations were considered as a reference point in the comparison between three scenarios (see table 5). From the distance point of view, second layout looks the most promising since the total monthly travel distance between operations is 1 377 607m. However, it does not differ much from the first layout with the distance longer by 1630m. The third layout provides the longest way that employees would have cover each month. When recalculating the travel distance according to the forklift speed (approx. 10km/h with the load), Layout I and II, consume monthly 119h and 120h for traveling respectively. The travel in Layout III would take 144h per month.

Apart from the travel time and distance, the table below shows the space that is available for each product group. For the better understanding, it was compared with the actual inventory requirements that both companies have. Minor differences can be noticed between alternative layouts, however all of them meet the space requirements.

What is more, the rough estimation of available empty space on the racks was made. Despite the fact that all layout designs depict wide aisle solution, the estimation of pallet and cages position was made also for the narrow, 1,8m aisles. It should be noted that only the racking system located on the left part of the layouts can be changed to the narrow aisle. The blue rack on the right side cannot be moved and bulks cannot be operated with the narrow aisle forklift due to bulks dimensions.

For example, in Layout I, if the racking system of the Agility storage space was arranged according to the wide aisle, the number of pallet positions in the pink area would be equal to 11484. If the company decides to place bulks instead of the racks, the total amount that could be achieved is 720. On the other hand, if the company decides to implement narrow aisles the storage space will be increased by 9 racks or 7 bulk rows. In case of the extra pallet positions, the number would grow to 17478. Whereas the number of bulks would be equal to 1910, if used instead of racks. In the same manner, the remaining two layouts were analyzed. The most number of stock keeping units can be obtained thanks to the Layout III, in both cases of wide and narrow aisle.

	Layout I				Layout II				Layout III				
Travel	1 379 237				1 377 607 m				1 655 540 m				
	120 h				119 h				144 h				Positions Demand
Product Group 1	9324				9324				9072				8925
Product Group 2	666				666				666				400
Product Group 3	1332				1332				1332				900
Bulk	2280				3120				2340				3045
Bulk Extra	760				-				760				
NA Cages	2700				2700				2700				2632
NA Tires	3996				3996				3996				3491
NA Rims	3663				3663				3663				3046
NA Others	333				333				333				258
EMPTY positions	*EU pallet*		*Cage*		*EU pallet*		*Cage*		*EU pallet*		*Cage*		
	WA (3m)	NA (1.8m)	WA (3m)	NA (1.8m)	WA (3m)	NA (1.8m)	WA (3m)	NA (1.8m)	WA (3m)	NA (1.8)	WA (3m)	NA (1.8)	
	11484	17478	720	1910	10656	16650	720	2085	11988	17982	720	2085	

***Table 5** Alternative Layouts comparison*

6.2 Final result

The advantages and disadvantages of all three layout suggestions were analyzed and listed in the table below. The main disadvantages that were mentioned concern long distance travel, difficulties in managing the staff due to the separated operations, or smaller space utilization. The differences in both disadvantages and advantages are small which makes it more difficult to choose the most optimal solution. However, one layout design seems to be a bit better than the others.

Advantages	*Amring operations close to its warehouse* *Possibilities for future expansion in retail area* *Outbound and outbound sideloading separated* *Possibility of utilizing new space* *Less traffic due to separated operations*	*Shortest travel distance* *High level of pallet positions* *Low traffic* *Outbound and outbound sideloading separated* *Amring operations close to its warehouse*	*All operations close to each other* *High level of cage storing* *Separation of Inbound and Outbound* *Highest level of storing positions*
Disadvantages	*Less pallet positions* *Difficulty in monitoring the workforce* *Unused ceiling height in retail area* *Long distance to recycling area from mounting*	Additional recycling area needed Difficulties in managing the workforce	Not sufficient space for spare part storage Long distace from mounting to warehouse Huge traffic outside retail area

***Table 6** Pros and Cons of Layout Alternatives*

Alternative Layout II was suggested to be the most suitable solution for the merged companies of Agility and Amring. The following layout represents the trade-off between the space utilization and travel distance, which is important in every logistics center design. The parametric, that was achieved, meet the space requirements of both parties and provides sufficient space for the inventory. The shortest travel distance also has the significant meaning. It decreases the utilization of workforce, equipment and decreases operation time.

The study results were discussed with both Amring and Agility, which has the decisive voice in this case. The companies' representatives were concerned about the separation of operations of Amring and Agility. It has been seen as a disadvantage because of difficulties in staff management. However, authors believe that it is the safest option from all. The traffic is decreased which minimizes the risk of collisions. Also quite a lot of space is available around the mezzanine which enables its future development. However, the managing problem became such a big threat to the future joined company that the Agility representatives decided to choose Layout Alternative III, which is also a good option.

In order to support company's decision about the layout design, authors present some recommendations for the future study and continuous improvement (see Chapter 8).

7. Conclusions

This chapter sums up the study for master thesis project.

This Master Thesis aimed to propose a new layout of the combined warehouses, so that it can sufficiently accommodate the operations of two companies as well as enable improvement of space utilization and process efficiency. The literature describes various methods and procedures which should be followed in order to create the facility layout design. After the initial stage of the project and looking at different resources, Systematic Layout Planning was chosen as the major method in the case analysis. The main reason why it was used in the research is the simplicity of its phased methodology which practicality leads to rearrangement of existing facility or designing new one. SLP method can be supplemented by Systematic Handling Analysis. The combination of two methods gives more feasible and optimal results. The analysis of the facility layout planning design can provide more information which can result in an effective utilization of space, travel time and distance.

Qualitative SLP analysis was the tool used for investigating the relations between different company's departments. It gave the insight to space utilization and indicated the way in which the warehouse operations should be located. It resulted in creating three layout alternatives. Suggested designs are characterized by different features that aimed to meet the needs and expectations of both Agility and Amring. Not only daily operations and material flow were taken into account while designing the layout but also the contractual and constructional constraints were paid attention to. Further, SLP was followed by the qualitative SHA method which was the answer to travel time and distance. It also supported the decision making process regarding the optimal design solution.

Due to the multi-criteria approach and the analytical analysis, thesis project resulted in suggesting the logistics center layout design that accommodates two merged companies and increases their operations efficiency and space utilization. The validity of the study is proved by implementation of the methodology that is universal and could be generalized and used in different scenarios. However, the more complex and advanced settings might need to be supported by computer-aided simulation tools.

8. Further Recommendation

In this chapter, authors give the recommendations to Agility and Amring for the future, regarding chosen layout. The ideas for the further study, that would be complementary to the presented project, are given.

In order to gain more robust solution to the logistics center layout, the out of scope areas should be taken into consideration in the further studies. The recommendation is to focus more on the inventory management and production flow optimization. Investigation of aspects like Warehouse Management System and production improvement methods would significantly contribute to the warehouse operations efficiency and space utilization. It is of interest to recommend measuring the efficiency of the chosen layout as well as implementation of the more complex goods classification according to the frequency of movement.

An evaluation of the chosen layout alternative, after implementation, could add value to the study. This would aim to indicate certain KPI's for the further performance improvements. Not only warehouse physical change should be monitored but also the human behaviour. It should not be forgotten that employees from shop floor know the best which way of working is more efficient and convenient. Both Agility's and Amring's staff was a big help during this project and creation of new layout design. It is therefore to be recommended to interview more respondents from the shop floor level regarding changes. It will surely provide robustness to the continuous improvement, which is very important aspect in terms of business development.

It has been left for further investigation whether the company should implement narrow or wide aisles. In order to make this decision, it is good to consider the cost factor as well as the potential of growth which will indicate the need for increased or decreased number of pallet positions. Hence, it will also result in making decision regarding investing in new narrow aisle forklifts. Moreover, it is suggested to reconsider the alternative racking system setup (e.g. fishbone layout or optimal cross aisle layout) in order to decrease the travel distances between departments (see Fig 28 and Fig 29). It concerns route planning to minimize traffic and avoid collisions as well (Cisco-Eagle, 2016).

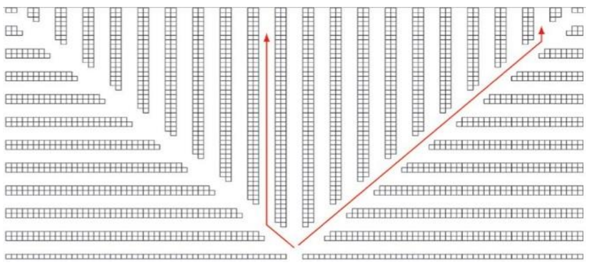


Figure 28 *Fishbone Layout (Cisco-Eagle,2016)*

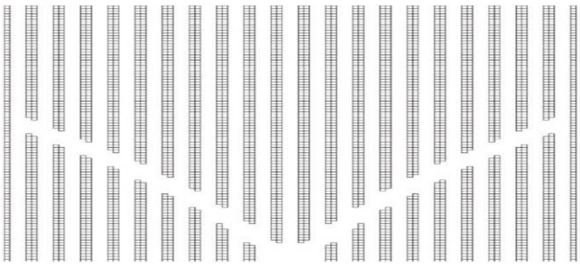


Figure 29 *Optimal Cross Aisle Layout (Cisco-Eagle, 2016)*

Above all, it is highly recommended to conduct cross training for employees in order to distribute the workload evenly between all departments. On first hand, workers could be a big support to each other when the one operation requires more attention than another. Additionally, cross-training could solve the absence and staff shortage problems in case of somebody's sickness. It should be mentioned that management team has a responsible task of following up the change concerning merger. It is important to manage the change properly involving people.

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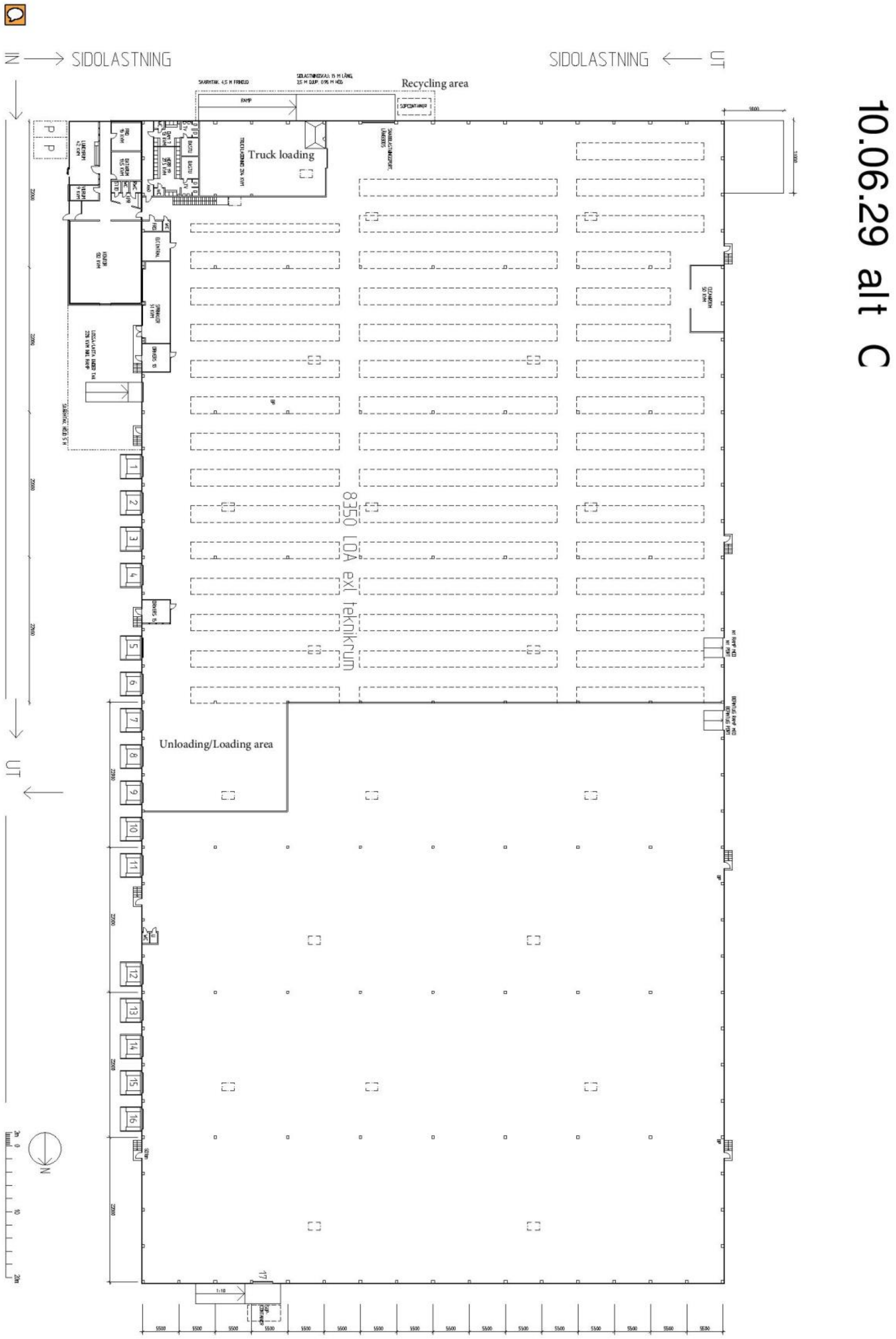
Appendix A – Agility Current Layout



Appendix B – Amring Current Layout