



**jamk.fi**

# **Designing the warehouse and improving the layout of JAMK Bio-Economy Campus**

Yasaman ZandMiralavand

Bachelor's thesis

December 2018

Technology, communication and transport

Degree Programme in International Logistics Engineering

**Jyväskylän ammattikorkeakoulu**

JAMK University of Applied Sciences

Author(s) ZandMiralavand, Yasaman	Type of publication Bachelor's thesis	Date December 2018 Language of publication: English
	Number of pages 63	Permission for web publication: (Yes)
Title of publication <b>Designing the warehouse and improving the layout of JAMK Bio-Economy Campus</b>		
Degree programme Degree Program in International Logistics Engineering		
Supervisor(s) Kervola, Henri		
Assigned by JAMK Institute of Bio-Economy , Ms. Minna Lappalainen		
Abstract  <p>Layout planning means arranging facilities and resources in order to increase productivity and efficiency in a business company. Moreover, it results in having smoother material flows and in preventing wasting time and energy.</p> <p>The main objective of the study was to improve the layout of the JAMK Bio-Economy Campus and determine the best location for a warehouse. There were many items that had reached their obsolete-status but had not been discarded. Therefore, there was not sufficient space for storing all the necessary components. As a result, many of the items were kept in the laboratory or in the yard, which had affected the appearance of the campus. In fact, interviewing the staff was a significant help in finding the main goal.</p> <p>For the theory part, data was collected from different sources and literature reviews. In addition, both quantitative and qualitative research approaches were used in order to find the answers for the research questions of the study.</p> <p>As the result of the study, three distinct warehouse locations and four different layout designs were proposed for comparison. Finally, the most preferable one was chosen according to the Head of the institute and the author's opinion.</p> <p>In conclusion, the recommended solutions enhanced the layout, which could lead in raising the capacity and work rate. Furthermore, the campus looked more organized compared to its earlier condition.</p>		
Keywords/tags ( <a href="#">subjects</a> )		
Miscellaneous ( <a href="#">Confidential information</a> )		

## ACKNOWLEDGEMENT

My four years of journey in studying this bachelor program has ended and I am deeply proud to be graduated from JAMK University of Applied Sciences.

First of all, I would like to express my gratitude to Mr. Henri Kervola, my thesis instructor, for sharing expertise, valuable guidance and encouragement in every step of this research.

Secondly, I would like to thank Ms. Minna Lappalainen, director at Institute of Bioeconomy, Mr. Jarno Liimatainen and all the employees at JAMK Institute of Bio-Economy for giving me this incredible opportunity to work with them.

Special thanks to Mr. Tommi Franssila, my mentor, and Mr. Sami Kantanen, Head of Logistics department, and all of my lecturers for their continues support, supervision and assistant.

I am also grateful to Mr. Antti Vanhala, JAMK project engineer, because without his contribution and aid I would not be able to start my thesis.

I would also like to express my appreciation to Mr. Petri Vauhkonen, Logistics senior lecturer, as the second instructor of this thesis and Mr. Hannu Ryyänen, JAMK Senior Lecturer, for his beneficial and valuable guidance and advice regarding language editing of this thesis.

Finally, I would like to express my profound gratitude to my husband and my family who provided me with unconditional support throughout these four years of studying and writing this thesis. This accomplishment would not have been possible without them. Thank you so much.

Yasaman ZandMiralavand

## Contents

<b>1</b>	<b>Introduction.....</b>	<b>4</b>
1.1	Background.....	4
1.2	Introduction to the case study .....	4
1.3	Topic .....	6
1.4	Goal/main objective .....	6
1.5	Research questions.....	6
1.6	Scope of the study .....	7
1.7	Framework of the report.....	7
<b>2</b>	<b>Research procedure .....</b>	<b>8</b>
2.1	Research approach .....	8
2.2	Research strategy/Data collection process .....	9
2.3	Research methods .....	10
<b>3</b>	<b>Theory .....</b>	<b>11</b>
3.1	What is a warehouse? .....	11
3.2	Warehouse design .....	12
3.3	Warehouse building .....	14
3.4	Warehouse layout .....	16
3.5	Safety.....	19
3.6	Kind of accidents in Logistics area .....	19
3.7	Layout and design.....	21
3.8	Work safety for pallet racking .....	21
3.9	Common risks in a warehouse.....	22
3.10	First Aid.....	24
3.11	Fire safety .....	24

<b>4</b>	<b>Empirical findings</b> .....	<b>25</b>
4.1	Company presentation: JAMK Institute of Bio-Economy .....	25
4.2	Current status .....	26
4.3	Problem diagnosing .....	26
<b>5</b>	<b>Development solutions</b> .....	<b>29</b>
5.1	Disposal of inoperative items .....	29
5.2	Warehouse location .....	30
5.2.1	Warehouse Location 1 .....	31
5.2.2	Warehouse location 2 .....	33
5.2.3	Warehouse location 3 .....	35
5.3	Warehouse layout design .....	36
5.3.1	Warehouse layout design 1 .....	40
5.3.2	Warehouse layout design 2 .....	42
5.3.3	Warehouse layout design 3 .....	45
5.3.4	Warehouse layout design 4 .....	46
5.4	Warehouse addressing system .....	47
5.5	Status after the author's recommendations .....	50
<b>6</b>	<b>Research result</b> .....	<b>51</b>
<b>7</b>	<b>Further recommendations</b> .....	<b>54</b>
<b>8</b>	<b>Conclusion</b> .....	<b>55</b>
<b>9</b>	<b>References</b> .....	<b>56</b>

## Figures

Figure 1	JAMK Bio-Economy Campus layout .....	5
Figure 2	Comparison between qualitative and quantitative research approaches ....	10

Figure 3 Fatal injuries to employees in logistics by kind, 2009/10 to 2013/14 combined .....	20
Figure 4 JAMK Institute of Bio-Economy status, yard .....	27
Figure 5 JAMK Institute of Bio-Economy current situation, laboratory.....	28
Figure 6 JAMK Institute of Bio-Economy status, yard .....	28
Figure 7 Warehouse location 1.a .....	32
Figure 8 Warehouse location 1.b .....	33
Figure 9 Warehouse location 2 .....	34
Figure 10 Warehouse location 3 .....	36
Figure 11 Pallet collars .....	38
Figure 12 Pallet collars .....	38
Figure 14 Aisle width calculation (Ast) based on VDI 2098 .....	39
Figure 14 Mezzanine floor.....	41
Figure 15 Warehouse layout design 1.....	42
Figure 16 Warehouse layout design 2 .....	44
Figure 17 Drive-in racking .....	44
Figure 18 Warehouse layout design 3 .....	45
Figure 19 Warehouse design 4.a .....	46
Figure 20 Warehouse design 4.b.....	47
Figure 21 Warehouse design 4.c .....	47
Figure 22 warehouse addressing system .....	49
Figure 23 warehouse addressing system .....	50
Figure 25 Final warehouse location a.....	52
Figure 26 Final warehouse location b.....	53
Figure 26 Final warehouse layout design .....	54
Figure 27 Final warehouse layout design (considering enlargement).....	55

## Tables

Table 1 The list of the items required to be stored in the warehouse.....	30
Table 2 Aisle width required at JAMK's warehouse .....	39

# 1 Introduction

In this section, a general background and study case are introduced and it is followed by presenting the goal of the project and research questions.

## 1.1 Background

According to Kassir (2014-2015), "layout planning is deciding on the best physical arrangement of all the resources that consume space within a facility." In a simple word, layout planning is finding the most appropriate location for all machines, equipment, office areas and employees. In real business world, the organization and planning of the resources might be adjusted whenever there is a change in the operations or dimensions of the building, a new employee added to the team or new facilities are made. (Kassir 2014-2015)

Having a decent layout planning affects the efficiency and productivity at work significantly as it could stop wasting time, energy and resources. Moreover, developing the communication and interactions between the employees in an organization and having better flow of information, could be achieved by planning an accurate and suitable layout. In addition, Kassir (2014-2015) emphasize that "Similarly, in retail organizations layout can affect sales by promoting visibility of key items and contributing to customer satisfaction and convenience. Layout planning affects many areas of a business, and its importance should not be underestimated." (Kassir 2014-2015)

## 1.2 Introduction to the case study

This research was conducted in cooperation with the JAMK Institute of Bio-Economy which is located in Tarvaala, Saarijärvi. The institute has provided agricultural education for nearly 150 years. Since the first meeting at JAMK, it could be seen that both parties had an urge to start this project as it was a perfect opportunity for the author to apply the knowledge gained during four years of studying logistics to a real life case. Moreover, providing a planned and organized layout, result in maintaining different equipment in a decent condition, having smoother material flow and increasing the safety.

In the current situation, the JAMK Bio-economy Campus consists of three buildings (see Figure 1): one building is used as a laboratory, the offices are located in another building and last one is the library. Outside of the buildings, in front of the laboratory, there are two warehouses, a few containers and some other equipment, which are kept outside, as there is no adequate space to store them.

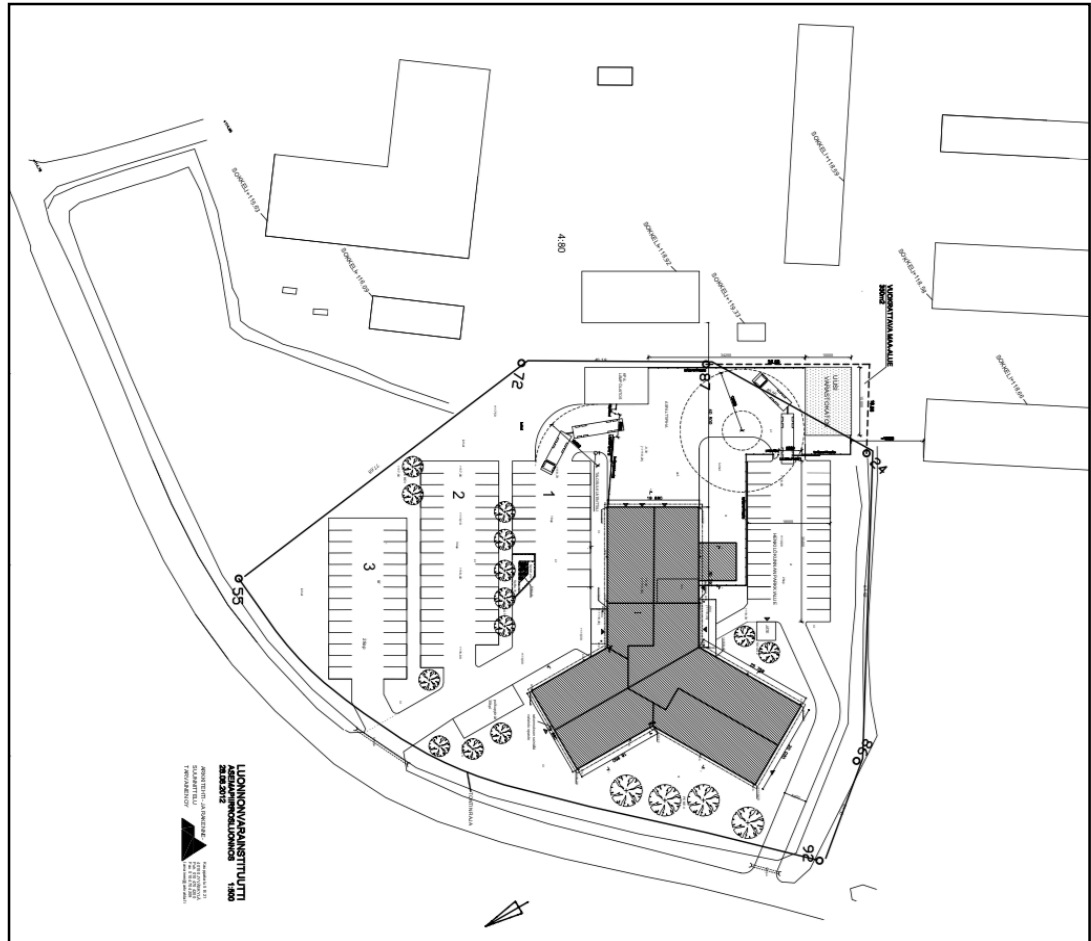


Figure 1 JAMK Bio-Economy Campus layout

As the Head of the institute stated, a new road was going to be built for truck traffic which would cross the area near the laboratory in order to avoid truck transportation from the staff parking area and make the loading and unloading easier and faster. Hence, there are certain main problems that required to be solved by this project. The Head of the institution wished to improve both the layout design, which included planning a new warehouse and organizing the items kept in the yard, and the efficiency of material flow.



### 1.3 Topic

The topic of this thesis is, Designing the warehouse and improving the layout of the JAMK Bio-Economy Campus.

### 1.4 Goal/main objective

The goal of the thesis was to improve the layout, find the best location for the warehouse based on the material flow and truck traffic in the yard and propose the most effective warehouse type based on the current condition. By enhancing the current layout and providing new warehouse design, all items would have a proper space for storing and keeping in suitable condition. Accordingly, the material flow would be smoother which could result in accelerating the productivity, saving time, energy and money. Having more organized warehouses would increase the accuracy as well. Besides, the repetitive tasks, such as moving items between the laboratory and the warehouse because of poor weather condition (especially in winter time) and not having proper storage planning, could be eliminated.

### 1.5 Research questions

In order to meet the goal of this project, the author tried to find the answers to the following questions:

1. How can the warehouse layout be designed?

Ahead of starting the designing process of a warehouse, it is vital to examine all the different resources and the assignor's requirements in order to find the best solution.

2. How can the layout be improved considering the truck traffic?

As it was mentioned above, a new road is going to be constructed to avoid truck transportation from the main parking area. By accomplishing this project, the author provided distinct alternatives for enhancing the layout that could result in having a smoother truck traffic.

3. How can the productivity be improved in the laboratory and warehouse?

Having a well-planned and organized warehouse helps the employees to raise their efficiency at work and prevents wasting time and energy.

#### 4. How can work satisfaction and tidiness be improved?

Considering a specific location for each item, makes the warehouse and laboratory look tidy and clean. Accordingly, every item can be found easily without spending extra time and as a conclusion work pace and proficiency are improved.

At the end of this thesis, the research questions above are answered and different alternatives are introduced and described.

### 1.6 Scope of the study

This project focused on designing the layout of a warehouse, providing different alternatives for storing items and some basic solutions for increasing the productivity and tidiness. However, it did not include the construction process of the warehouse and the materials required. Moreover, the data provided by JAMK was analyzed to find the suitable warehouse area that would meet the current and possible future demand of the Institute.

### 1.7 Framework of the report



#### I. Theory

In this section, the reader is presented with the required theoretical background for this project. (Rosinska, Chillara 2017)

#### II. Research procedure

This chapter points out the research and data collection methods that were implemented during this project. (ibid.)

#### III. Experimental findings

This part starts with a presentation of the JAMK Bio-Economy Institute and continues with a description of the current status of the JAMK warehouse and laboratory and a list of the items needed to be stored. (ibid.)

#### IV. Analysis

In this section, the author recommends different alternatives for warehouse location and designing the layout. (ibid.)

#### V. Results

Comparisons between the suggested alternatives and an optimal solution are presented in the result section. (ibid.)

#### VI. Conclusion

This chapter presents a summary of the whole project. (ibid.)

## **2 Research procedure**

This section clarifies the research procedure that was carried out in order to achieve the project's goals. Moreover, it describes the research approach, data collection process and research methods.

### **2.1 Research approach**

The research project started by visiting JAMK Bio-Economy Campus and observing its condition. During the visit, first the problems and challenges were first explained and the JAMK requirements discussed. At this stage, the general aim of the study was identified, but for gaining more accurate information, a second visit was planned. Then, the JAMK status was generally analyzed in order to summarize the project's objectives in to three to four main research questions, which were the foundation of the whole project.

The next step was to compile a theory section by means of literature studies. The first phase of the theory was about finding the most suitable research strategies and methods. The second phase was about collecting relative data from different sources, such as interviewing the Head of institute and the employees as well as literature studies,

in order to help the author to detect the answers to the research questions and propose suitable warehouse layout designs and possible solutions for improving the productivity at JAMK.

The research process continued by suggesting diverse warehouse layout design alternatives and by choosing the optimal one. Most of the research and data collection was carried out at the beginning of the project, but, some exploration was done at the last stages of the research work as well.

## 2.2 Research strategy/Data collection process

Research strategy simply means how the whole research is done and what kinds of processes and activities it includes.

According to Wedawatta, Ingirige, and Amaratunga (2011, 2), research strategies could be categorized as “case studies, experiments, surveys, action research, grounded theory and ethnography are examples of such research strategies.”

Wedawatta, Ingirige, and Amaratunga (2011, 2) also mentions that “A case study is documented as an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and context are not clearly evident.”

Since this project aimed to answer the research questions by analyzing the current situation of the JAMK Bio-Economy Institute and find solutions for improving the condition, then the case study design was chosen.

According to Newman, I., R. Benz, C., S. Ridenour, C. (1998,2), the quantitative research approach is done based on a concept or theory in order to prove the validity of it. Alternatively, in the qualitative research approach the reality or fact is observed in order to create or develop a theory to explain what happened.

Newman and colleagues have stated that William Firestone (1987), in an article in the *Education Researcher*, differentiates qualitative from quantitative research based on four dimensions: “assumptions, purpose, approach, and research role.”

The idea that perception of a truth is either based on facts or human interactions is named assumption. Recognition or searching for the reasons behind a phenomenon

could be named as the purpose of a research. Studying cultures and people or investigating new phenomenon could be assumed as the categorization of a research approach. Being fully involved or not completely connected to the case could determine the researcher's role. (Newman et al. 1998, 2-3)

Below is a comparison between the qualitative and quantitative research approaches:

	Qualitative	Quantitative
Conceptual	Concerned with understanding human behaviour from the informant's perspective  Assumes a dynamic and negotiated reality	Concerned with discovering facts about social phenomena  Assumes a fixed and measurable reality
Methodological	Data are collected through participant observation and interviews  Data are analysed by themes from descriptions by informants  Data are reported in the language of the informant	Data are collected through measuring things  Data are analysed through numerical comparisons and statistical inferences  Data are reported through statistical analyses
<i>Source: Adapted from Minichiello et al. (1990, p. 5)</i>		

Figure 2 Comparison between qualitative and quantitative research approaches

This case study relied on both qualitative and quantitative research approaches. Therefore, it was a mixed method study. In order to meet the projects goal and answer the research questions, some data was collected by interviewing the staff, Institute for example the Head of institution and the Warehouse Manager (qualitative approach). In addition, for parts of the project, numerical data was collected and analyzed (quantitative approach).

### 2.3 Research methods

In order to achieve the project's objectives, distinct research methods were used. These methods are listed and explained below:

1. Interview with the Head of JAMK Bio-Economy Institute, laboratory technician and warehouse coordinators.

These gave more realistic explanations of the existing problems, and difficulties, such as lack of space management, as well as safety and energy issues., In addition, the interviews also gave information about people's wishes and expectations. The author believes that, this research method was one of the most reliable one as it provides the possibility to use the experience of people who worked there. This was hoped to lead to better and more authentic decisions.

2. Analyzing internal data

A list of all the items required to be stored in the warehouse and JAMK current layout design and measurements were provided by the warehouse coordinator. Studying the data provided, helped the author in the process of determining the most suitable layout design for the new warehouse.

3. Literature study

During this project, author used different materials, such as books, articles and other bachelor and master theses for understanding and analyzing the current situation at the JAMK Bio-Economy Campus. This was also needed for forming an appropriate research theory background for finally proposing different alternatives.

### **3 Theory**

In this section, a relevant theory background is provided in order to make the research paper more comprehensible and easier to follow for the reader.

#### **3.1 What is a warehouse?**

As O'Byrne (2017) states, a good definition of a warehouse is "a planned space for the efficient storage and handling of goods and materials".

Based on Waters (2003,283), warehouses are not only used for storing different kinds of material and component, but also they can be designed in a way to add value to a product. Many companies assign their warehouse as a place where varied kinds of ac-

tivities concerning the products are done. Material consolidation and sortation, inspection and dividing large supplies into smaller amounts could be named as some of these activities. Moreover, warehouses could be used as stations where the products are taken under different actions such as labeling and packaging which would prepare them for sending to retailers or shops in order to be consumed by customers.

### 3.2 Warehouse design

According to Gauriloff (2012,10), Gu (2010) states that the procedure of designing the layout of a warehouse could be divided into five main sections which are: appointing the most suitable approaches for warehouse operations, choosing the equipment required in the warehouse, analyzing the arrangement and formation of the warehouse, deciding on the appropriate dimensioning and defining the layout.

Based on Baker and Canessa, (2009,26), the steps used by warehouse design companies are listed below:

1. *Define system requirement*
2. *Define and obtain data*
3. *Analyze data*
4. *Establish unit loads to be used*
5. *Determine operating procedures*
6. *Consider possible equipment types*
7. *Calculate equipment capacities*
8. *Define services and ancillary operations*
9. *Prepare possible layouts*
10. *Evaluate and assess*
11. *Identify the preferred design*

According to O'Byrne (2009), Colin Airdrie (2009) states that, all types of storage facilities or distribution centers such as a small or local store selling spare parts, a supplier of raw material or a large distribution center providing services to a wide network, should be designed based on four key factors. These factors are introduced and explained below.

#### 1. Flow

It can be described in two parts. First, it refers to the physical arrangement of components which means that where each item is located and what kinds of handling

equipment are used. Secondly, it indicated the arrangement between different activities in a warehouse. It is vital to manage the interactions between different activities and processes in order to prevent high traffic or probable clashes in the work. (ibid.)

## 2. Accessibility

It is mainly concerns the fact that how easily an item could be reached in a warehouse. Accessibility is an important issue especially in the businesses that have a fast moving stock or the responding time to the customer's order is quite short. However, usually providing a high level of accessibility requires a large space. Therefore, there should be a logical and economical justification for the gap between desirable level of accessibility and space usage. (ibid.)

## 3. Space

Regarding the space usage in a storage or distribution facility, the most of the available area should be assigned to storing different component and warehouse operations and procedures. The rest of the space could be used for reserved storage, locating empty pallets, battery charging and offices. (ibid.)

## 4. Throughput

It is not only about identifying and classification of the products that move through the warehouse, but also it concerns the products' special features and velocity. Dimensions, handling requirements and other characteristics such as hazard or fragility could be named as product's features. Based on O'Byrne (2009), Colin Airdrie (2009) defines velocity of the product as "the volumes moving through the warehouse on a daily basis". Analyzing the throughput data gathered in a long period, could provide valuable information for designing the layout of a warehouse as well as it decreases the possibility of future risks and uncertainties. (ibid.)

Referring to JAMK Bio-Economy case study, the items that are needed to be maintained in the warehouse, have different shapes and require distinct conditions. Some of them could be stored on pallet but some other should have their own space without placing anything on top of them. Moreover, forklifts should be kept in a warm place as the cold weather damages them easily.

## **Characteristics of an ideal warehouse**



Before proposing the most suitable warehouse types concerning this project, it is beneficial to mention KJ Staff (2017) opinion on the characteristics of an ideal warehouse.

- Location

It is ideal to locate the warehouse facilities in a place that could be accessed easily by different transportation means like railways, airports, seaports and roads. (ibid.)

- Handling tools

It is important to use appropriate handling device based on the products' features. But, mechanical device makes the loading and unloading much easier and decrease the handling costs. (ibid.)

- Storage space

There should be sufficient room for locating all the items in proper condition. Besides, if the facilities would be used for storing perishable products, cold storage should be considered as well. Moreover, some products are required to be maintained under special circumstance like specific temperature or being protected from sunlight, moisture, rain and wind. (ibid.)

- Safety and security

The warehouse should be provided by essential tools and device like firefighting equipment to be secured from probable accidents and losses. (ibid.)

### 3.3 Warehouse building

This section explains the general requirements and constraints that should be considered before structuring the warehouse building based on Segerlund and Halbeisen (2015) opinions.

- Height of the building

The building or the warehouse operations should be designed and planned in a way that the maximum of the vertical space would be usable. (Segerlund and Halbeisen 2015, 54)

- Building columns

According to Segerlund and Halbeisen (2015) "structural columns are an obstruction for the purpose of an efficient palletized warehouse. To eliminate obstruction, columns should be sandwiched between racking rows positioned back to back."

- Other obstacles

That is any structural element resulting in non-rectangular warehouse areas, should be omitted by defining space used for any warehousing solution to be a best fit rectangle (or several rectangles). (ibid., 54)

- Inbound and outbound flows

In the warehouses, longer traveling distance is equal to more costs. Therefore, it is noteworthy to plan and arrange the warehouse processes in a way to avoid unnecessary movements as much as possible. (ibid., 54)

- Floor flatness

Having the right floor flatness is an important matter in planning and designing the layout of a warehouse especially,, in the warehouses in which there is racking system. (ibid., 54)

- Warehouse building

The environmental condition such as temperature and humidity could have a significant impact on formation different parts of the building like electrical installation. (ibid., 55)

- Building atmosphere and temperature

All the component kept in the warehouse do not require same condition, some of them are more sensitive to environmental changes while others might not be harmed so easily. Therefore, it is both important and critical to maintain the building temperature in optimum condition. According to Segerlund and Halbeisen (2015) "Standard warehouse solutions are designed to operate optimally between +5 C and +40 C. outside this range, special and costly measures are required to accommodate plant equipment." Besides, special material like explosive substances and the tools that are used for handling them should be protected and supervised appropriately in order to avoid any problem. (ibid., 55)

## **Size of warehouse**

In reality, there are many issues such as level of customer service and type of business, which, have significant impact on deciding the ideal warehouse size. According to Waters (2003), below are some general hints that should be taken in to account when considering the appropriate warehouse size.

- *The number of products using the warehouse*

- *The type of demand for each product, how much it varies, average order size, and so on*
- *Physical features of the products, particularly size and weight*
- *Special storage condition, such as climate control, packaging and so on*
- *Target customer service level*
- *Lead time from suppliers and promised to customers*
- *Economies of scale*
- *Type of material handling equipment*
- *Layout of storage and related facilities (284)*

### 3.4 Warehouse layout

Planning the warehouse layout is one of the most important and challenging issues regarding warehousing. Warehouse layout planning means, deciding on the location of storage racks, loading and unloading area, offices, rooms, equipment, machines and other facilities.

A well-designed layout can increase the efficiency of warehousing notably, as it prevents wasting time and raises productivity. For example, the most frequently used items should be placed in the most visible and accessible areas in order to avoid unnecessary traveling time.

As stated in Waters (2003, 292), Stevenson (1993) summarizes this by saying that: "layout decisions are important for three basic reasons: (1) they require substantial investment of both money and effort, (2) they involve long-term commitments, (3) they have significant impact on the cost and efficiency of short-term operations."

At JAMK Institute of Bio-Economy, there is a need for two types of warehousing designs. A temperature and humidity controlled warehouse is required for forklifts and different kinds of machines and a simple or tent type warehouse is required for other equipment that do not need special condition. In wintertime, the forklifts and machines are kept in the laboratory as the outside weather might result in damaging the equipment. Given that, the laboratory gets occupied and there would not be enough space for employees to do their tasks. Moreover, it is essential to keep the woodchips in warm place as they get frozen in winter time and cannot be used before getting warm again. Consequently, they are brought in to the laboratory and kept there until the ice melts and they become usable again. All these problems could be solved by planning a warehouse which, has heating system.

**Heating, ventilation and air conditioning (HVAC)**

Warehouse operations consume high amount of energy which means spending a lot of money. Therefore, managing the energy consumption would result in saving money by decreasing the costs as well as having a more environmentally- friendly building. As Kelsey Raftery (2016) mentions “heating, ventilation and air conditioning (HVAC) accounts for roughly 30 percent of total energy cost in a warehouse.” (Kelsey Raftery 2016.)

As it was mentioned before, maintaining the temperature in an optimal level, is one of the most important and crucial issues regarding constructing a warehouse. Because, some material and components are sensitive to the environmental changes. Controlling the humidity is as vital as controlling the temperature since some material like wood or fabric could be damaged easily in moist environment. Therefore, the ideal solution would be climate-controlled storage where the temperature and humidity fluctuate very little. (What’s the difference between temperature-controlled and climate- controlled storage? 2018.)

Another solution would be temperature-controlled warehouses where the inside and outside temperature differs several degrees (about 10 degrees). It would be a suitable choice for the items that are required to be stored and protected from harsh weather condition for a long period. (What’s the difference between temperature-controlled and climate- controlled storage? 2018.)

**Layout of racking**

Typically, different kinds of racking systems are used in warehouses or storage areas. In practice, the racking system and layout design depend on the items and handling equipment used. Generally, bulk and heavy products are stored in one part of the warehouse and they are moved and handled with the help of forklifts or cranes. In the other hand, there are some items which, are placed on the pallet and are located on the shelves. Besides, there are some small items that can be stored in containers or bins.

In most of the warehouses, a series of aisles can be seen. The width of aisles depends on the handling equipment and the goods stored on the shelves. For instance, if some small boxes are placed on the shelves, then there is no need for having wide aisle, as

they can be reached by hand without help of equipment, but they should not be so high. On the other hand, for the pallet racking, the width of aisle is planned based on the handling equipment such as forklift or crane dimensions.

Planning the details of the layout depends on the available financial resources, area and physical constraints. As it was mentioned before, planning and arranging warehouses are costly, therefore, we should use the most of floor space in order to avoid excess expenses, given that fact, one handy solution is making higher shelves.

### **Materials handling**

As it is stated in Waters (2003), "materials handling is concerned with movements of materials for short distances generally within a warehouse, or between storage areas and transport." (297)

There are two types of costs in the warehouses: first one is the fixed costs such as rent and depreciation and second one is variable costs which, come from more detailed issues in the warehouse like the time and methods of handling different items. Whenever, an item moves in a warehouse, it takes time, money and there is always probability for damages. Therefore, it is clear that even a small change in every employee's function or arranging material in order to reduce the unnecessary movements can lead to a considerable difference in the warehouse operations.

In JAMK Bio-Economy Campus, based on the number of items and their nature, manual warehousing is operated. In manual warehouses, employees control all the movements' aspects although, there is some equipment such as hand trucks for moving pallets to help them. In the manual warehouses, the condition such as the temperature and lighting systems should be appropriate for working. In addition, height of shelves should be about two meters.

### **Material handling equipment**

There are distinct factors that affect the process of decision making about choosing the most suitable handling equipment for a warehouse. Some of these factors are: amount of available budget, product type, customer service level, warehouse dimensions and design.

### 3.5 Safety

Health and safety issues are one the most vital concerns for companies and institutions who have laboratories and warehouses. Besides, this can be a high-cost area, not only in providing a safe environment but also the cost of not providing a safe and ensure place to work (Richards 2011, 269). Therefore, in a working place all kinds of risks should be recognized, analyzed, controlled and managed by effective actions. Preparing a healthy and safe working environment should not be only seen as a duty, as it could cause many decent consequences, such as, less accident hence less worker's absence, increasing the productivity, building better reputation, having happier and healthier employees.

### 3.6 Kind of accidents in Logistics area

*According to Health and Safety Executive (HSE), over the period from 2009/10 to 2013/14p, the most common cause of a fatal injury to logistics employees were being struck by a moving vehicle. (In 2013/14p, for all industries, vehicle injuries were the third most common cause, with falls from height the most common) 41 out of 44 fatal injuries were in land transport and warehousing. (Statistics report for the Logistics industry (road haulage and warehousing), 2009/10 to 2013/14p (provisional) 2013/14)*

*The main kind of major/specified injury was a slip or trip. (This is the most common kind of major injury across all industries.) Slips and trips accounted for about two thirds of major/specified injuries in the other logistics (postal and courier and water transport) industries but only just over a third of injuries in transport and warehousing. Falls from height, handling injuries and being struck by a falling object accounted for a much higher proportion of major/specified injuries in transport & warehousing." (ibid.)*

*HSE also mentions that, "slips and trips were also the top cause of over-3-day and over-7-day injuries in other logistics, accounting for about four in ten injuries. Handling injuries were the top cause of over-3-day and over-7-day injuries in transport and warehousing, also accounted for about four in ten reports. (ibid.)*

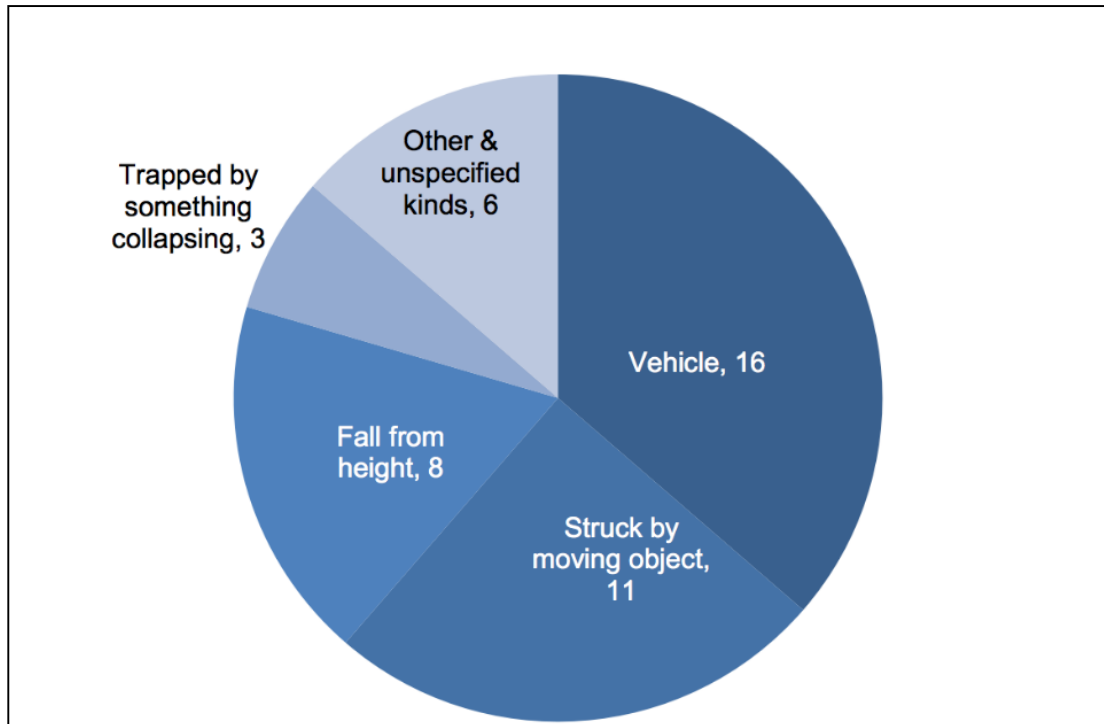


Figure 3 Fatal injuries to employees in logistics by kind, 2009/10 to 2013/14 combined

Besides, the injuries mentioned above, OSHA (US Occupational Safety and Health Administration) also cites the following causes of injuries:

- *Unsafe use of forklifts*
- *Improper stacking of products*
- *Failure to use proper personal protective equipment (PPE)*
- *Failure to follow proper lockout/tag out procedures, i.e. prevent equipment from being accidentally energized*
- *Inadequate fire safety provisions*
- *Repetitive motion injuries (Richards 2011, 270)*

### **Responsibility at work**

Actually, everyone's effort and commitment to regulations, is required to have a safe and healthy working environment. Richards (2011) classifies the responsibilities into three groups. Firstly, the employer is responsible to clarify the health and safety regulations, provide the staff with essential education, training and safety equipment. Moreover, the supplier should make sure that his products align with the company's

requirements and they are safe to be used. In addition, all the employees are responsible to collaborate with the employer, participate in the training programs, use the equipment properly, according to regulations and report issues. (Richards 2011, 271)

### 3.7 Layout and design

In order to have a safe working environment, it is vital to design a warehouse in which people and machines (such as forklifts) can move easily and safely. A well-designed warehouse can considerably reduce the number of accidents.

Points to consider when thinking about the warehouse design and layout are followed below:

- *Storage areas, aisles and gangways*
- *Pedestrian traffic routes*
- *Stairs and ramps*
- *Emergency escape routes (Richards 2011, 275)*

Besides, all the vehicles and equipment should be checked and controlled continuously. Additionally, maintenance actions should be taken continuously in order to prevent happening serious problems in a warehouse.

### 3.8 Work safety for pallet racking

Segerlund and Halbeisen (2015) mention that in European countries the guidelines regarding work safety are set according to national regulations. Also they should be in line with European principles. (60-61)

Some of these guidelines are listed below:

- *Protection against falling goods*
  - ✓ *Passages beneath racking are to be protected by wire or mesh grating against goods falling from above.*
  - ✓ *Single faced racking rows with an operational aisle to the rear are required to have their rearward side completely secured by appropriate fencing and back stops.*
  - ✓ *Outer frames are to have a height sufficient to prevent pallets from falling sideways.*
  - ✓ *Clearances in the racking are to be sufficient to allow for safe placement of goods.*
  - ✓ *Loading aids are to be safe and kept in good condition. (ibid.,61)*
- *Protection against collisions*
  - ✓ *Sufficient width of operational aisles.*



- ✓ *Sufficient lighting.*
- ✓ *Clear marking of driveways and walking areas.*
- ✓ *Clear and safe work organization.*
- ✓ *Clear separation of machines from workers. (ibid.,61)*
- *Protection against racking collapse*
  - ✓ *Sufficient width of operational aisles.*
  - ✓ *Protection of racking frames with impact protectors against impact by forklift.*
  - ✓ *Clearance in racking are to be sufficient for safe placement of goods*
  - ✓ *Clear marking and / or control of maximum weights allowed for storage in the racking. (ibid.,61)*
- *Protection against a dangerous environment*
  - ✓ *Fire safety rules including escape routes need to be on prominent display.*
  - ✓ *Sufficient lighting.*
  - ✓ *Atmospheric condition is to be such as prevent packaging collapse or corrosion. (ibid.,61-62)*

### 3.9 Common risks in a warehouse

As it was mentioned before, there are some common risks in warehouse operations that should be considered and appropriate actions should be set in order to avoid probable accidents. These risks and possible prevention methods are listed and explained below:

- Slips and trips

Within storage and warehousing industry, slips and trips are very serious problems. They are responsible for one-third of major injuries and a fifth of over-three-days absence injuries. Slips and trips could be avoided by regular inspection of the working environment. The floor should be even and cleared up from any spillage. Moreover, any kinds of obstacles should be removed specifically near doorways and on emergency routs. (Richards 2011, 277)

- Manual handling

In warehousing, manual handling can often cause work-related problems, including back pain and neck pain. Therefore, the risk of injuries should be reduced as far as possible. Wherever it is possible, the mechanical handling devices such as lift trucks, pallet rucks, trolleys and scissors lifts should be used. These devices help reducing the manual operations.

Besides providing required handling tools, sufficient trainings should be offered as well. Moreover, the height of items and component placed on the shelves should be considered carefully as moving them might be harmful to the employees. Additionally, having appropriate lighting in the working area would be really effective in decreasing the number of accidents. (Richards 2011, 277)

Moreover, there are specific regulations for using different equipment in warehouses. Richards (2011, 281) also emphasize that “all mechanical handling and lifting equipment is classed as “work equipment” and subject to PUWER (Provision and Use of Work Equipment Regulation).” The regulations require:

- ✓ *The inspection and maintenance of equipment;*
- ✓ *The provision of information, instruction and training;*
- ✓ *The marking of controls;*
- ✓ *That mobile work equipment for carrying persons is suitable;*
- ✓ *Protection from rolling over;*
- ✓ *Facilitate to prevent unauthorized operation;*
- ✓ *The provision of lighting equipment where necessary;*
- ✓ *The provision, where necessary, of devices to improve vision.*

- Working at height

Accidents that happen because of working at height is one of the most popular risks in a warehouse. The first advice, is avoiding working at height as much as possible, but if it would not be possible then it should be well planned and supervised continuously. Besides, all the equipment that are operate at height should be inspected regularly as well. (Richards 2011, 278)

- Vehicles

One of the most common accident in loading bay is called “drive-away”. “Drive-away” caused because of vehicle creep, where a lorry moves slightly away from loading dock or even in a worst case, driver moves the vehicle before the operators finish their work. Actually, this may cause serious injuries and even fatal.

The risk mentioned above is not the only hazard in loading bays. There are many trailers which, do not have sufficient and proper inside lighting system. Therefore, when an operator enters the trailer, he might hurt himself or probably, damage products and items. (Richards 2011, 278)

- Forklift trucks

Referring to Richards (2011, 279), “in accidents involving forklift trucks, 87 percent were attributed to counter-balance trucks. The highest number of accidents (48 percent) occur when stacking/retrieving goods and the greatest cause of accidents is being struck by a moving vehicle.” Below, there are some of guidelines from US National Institute for Occupational Safety and Health (NIOSH).

- ✓ *Make sure that workers do not operate a forklift unless they have been trained and licensed.*
- ✓ *Separate forklift traffic and other workers where possible.*
- ✓ *Install physical barriers where practical to ensure that workstations are isolated from aisles travelled by forklifts.*
- ✓ *Evaluate intersections and other blind corners to determine whether overhead dome mirrors could improve the visibility of forklifts operators or workers on foot.*
- ✓ *Do not put store bins, racks or other materials at corners, intersections or other locations that obstruct the view of operators or workers at workstation.*
- ✓ *Repair and maintain cracks, crumbling edges and other defects on loading docks, aisles and other operating surfaces. (Richards 2011, 279-280)*

### 3.10 First Aid

Given the risks in a warehouse, there is always probability of emergency situations and injuries, consequently, appropriate planning and facilities, such as a first aid box and a room (depending on the warehouse size) should be considered. It is recommended to appoint a person (not necessarily a first aider) who is responsible to do the initial actions in emergency situations, like bringing the first aid box or dialing emergency services. As Richards (2011) states in his book “as a general rule there must be at least one qualified first aider for every 50 people employed.” (282)

### 3.11 Fire safety

Fire safety is one of the most complicated and costly issues which, affects the warehouse design. Hence, it should be evaluated carefully and it is strongly suggested that a local fire safety inspector involved in the design process in order to be able to reduce the investment cost and fire risk as much as possible. (Segerlund, Halbeisen 2015, 58)

According to Richards (2011) employers should be provided with a plan which clarifies what expected from them to do in emergency cases. The plan includes following points:

- ✓ *Provisions for emergency exit locations and evacuation procedures*
- ✓ *Procedures for accounting for all employees and visitors*
- ✓ *Location and use of fire extinguishers and other emergency equipment (276)*

## 4 Empirical findings

### 4.1 Company presentation: JAMK Institute of Bio-Economy

As Paloniemi (2014) mentions that the Bio-economy is a growing industry in central Finland especially in Jyväskylä area. Paloniemi (2014) also emphasize that “The forest industry and related machinery and equipment construction produce over 50% of the industrial added value in the region. Over 85% of electricity and heat are produced using local fuels.” Moreover, the forest and biomass resources play an important role in developing the economy of this area. It has been planned to eliminate completely the consumption of fossil fuels in all field but traffic in Central Finland by 2020. (Paloniemi 2014.)

the Natural Resources Department of the Vocational Institute of North-ern Central Finland (POKE) and the JAMK Institute of Bio-Economy are located in Saarijärvi, Tarvaala campus which is well-known for the agricultural education it has offered for more than a decade. (The Tarvaala Bio-Economy Campus is developing 2014)

*The mission of JAMK University of Applied Sciences’ Institute of Bio-economy, located in Saarijärvi, is to serve as an international researcher, expert, trainer, entrepreneurship and business developer in the field of Bio-economy. The objective of the operations is to support entrepreneurship related to renewable energy, agriculture and clean water as well as a significant increase in employment in Central Finland. The focus areas of energy related development activities are biofuel production, quality management and logistics, combustion technology and emission control as well as entrepreneurship and business activities in the field of bioenergy. Such elements offer great prospects for raising the profile of Central Finland. (Paloniemi 2014.)*

## 4.2 Current status

The JAMK Bio-Economy Campus consists of three buildings: one building is used as a laboratory, the offices are located in another building and the last one is the library. Outside of the buildings, in front of the laboratory, there are two warehouses, a few containers and some other equipment, which are kept outside as there is not adequate space to store them.

The woodchip bags are stored in one of the warehouses in a way that all of them are placed on the ground due to the lack of an appropriate racking system. Therefore, almost two thirds of the warehouse are empty, as the warehouse height is not utilized efficiently.

In the second warehouse, different components, mostly heavy ones, are stored on the ground. There is the same problem in both warehouses that there is no sufficient and convenient infrastructure, such as a proper racking system and floor surface for having effective space utilization.

## 4.3 Problem diagnosing

According to the discussion with the Head of the institute, the laboratory and warehouse coordinators and employees, the most critical problem that the JAMK Bio-Economy institution faces at the moment is the lack of sufficient warehouse capacity, which has resulted in diverse difficulties and challenges. Due to the harsh Finnish weather, especially at wintertime, equipment and machines that works with electricity should be kept under special conditions in order to be stay in working condition at least for several years. However, in the current situation, there is no specific place for storing them. Moreover, many unnecessary items have not been disposed of for years, and they occupy considerable amounts of space in the laboratory or in the yard. In addition, space utilization is poor in the existing warehouses as the result of not having proper structures. Finally, no reserve space has been considered for further operations or more customers.

In the JAMK campus, the items are mainly divided in to two groups:

1. There are different elements, such as boilers and forklifts that are sensitive to cold weather and they are handled in the laboratory because there is no suitable place to store them. In the summer time, when the weather is good, they can be kept outside and in the wintertime, they are brought into the laboratory. In this situation, forklifts occupy a significant amount of space available in the laboratory, which results in causing problems for conducting activities there, especially the ones that need space.
2. Besides the components that were mentioned above, some other ones are not easily affected by cold weather. Most of these items are placed outside of the laboratory in the yard in distinct locations. (See Figures 4,5, and 6)



Figure 4 JAMK Institute of Bio-Economy status, yard



Figure 5 JAMK Institute of Bio-Economy current situation, laboratory



Figure 6 JAMK Institute of Bio-Economy status, yard

Because of a limited budget, there is no need to make two different buildings; one can be built and the space separated with a wall (this would lead to two rooms or sections). Then one section can have a special heating and ventilation system, and for other section, a pallet racking system is considered for smaller items and the ones that do not need special conditions. However, the optimal option would be having a fully heated warehouse.

## **5 Development solutions**

In this section, the author's suggestions and solutions in order to reach the project's goal, are explained. In addition, the possible locations of a new warehouse and the potential warehouse layouts are introduced.

### **5.1 Disposal of inoperative items**

The first action is finding the components whose service life and market value have ended. In this case, JAMK's policy should be followed, but generally, given the bookkeeping recordings, each item has a market value and it decreases when the item reaches to the end of its service life. Therefore, it is vital to check the items' database and make a list of the ones that should be discarded. This is called write off inventory, and it provides a clear view of what would be stored in the warehouse and how much space is needed.

Writing off inventory means removing some or all of the cost of an inventory item from the accounting records. The need to write off inventory occurs when it becomes obsolete or its market price has fallen to a level below the cost at which it is currently recorded in the accounting records. The amount to be written off should be the difference between the book value (cost) of the inventory and the amount of cash that the business can obtain by disposing of the inventory in the most optimal manner. (Bragg 2018.)

**What should be stored in the warehouse?**



Based on the author's discussion with the warehouse and laboratory coordinator, below is a list of existing items that are required to be placed in the warehouse. All the components are mentioned in the following table:

<b>Laite (item)</b>	<b>Pituus (length)</b>	<b>Leveys (width)</b>	<b>Korkeus (height)</b>	<b>Paino (mass)</b>
<i>Ariterm Bio Twin 500, boiler 500kW</i>	5,3m	2m	6,3m	3950kg
<i>Savukaasupesuri, smoke gas washer</i>	2m	1m	1,6m	
<i>Siilo, silo</i>	2,4m	2,1m	2,8m	940kg
<i>Vaaka (4), scale</i>	3,2m	3,2m	0,3m	
<i>Vaaka (2), scale</i>	1,5m	1,5m	0,3m	
<i>Vaaka (3), scale</i>	1,5m	1,5m	0,3m	
<i>Vaaka (5), scale</i>	1,5m	1,5m	0,3m	
<i>Vaaka (1), scale</i>	2,5m	2,5m	0,42m	
<i>Kuormaaja, loader</i>	4,7m	2m	3,3m	1150kg
<i>Trukki, forklift</i>	4,7m + piikit	2m	3,7m	4750kg
<i>Erka sininen seula, screen</i>	5,4m	3m	2,85m	980kg
<i>Teline, scaffolding</i>	4,4m	1,5m	1,1m	120kg
<i>Ariterm Biocomb 40, boiler 40 kW</i>	2,2m	2,5m	3,2m	690kg
<i>Pieni seula, screen</i>	3,4m	1,5m	1,84m	230kg
<i>Siilo (Mafa), silo</i>	2,62m	1,4m	2,4m	60kg

Table 1 The list of the items required to be stored in the warehouse

As it can be seen in the table, the items have different shapes, sizes and weights. Most of them are quite large, they require their own space in the warehouse. Therefore, stacking is not an applicable method for many of these elements.

## 5.2 Warehouse location

In the current situation, there are two operating warehouses. The main warehouse is located in front of the laboratory in which there are some of the machines and other

equipment, and the other one is used for storing the woodchips bags. The main warehouse does not have sufficient space for storing all the items, and the floor is not suitable for building shelves and a racking system there. In the second warehouse, the woodchips bags are located on the ground without anything on top of them, and therefore, the warehouse space is not used efficiently. In addition, none of the warehouses is heated. Eventually, in the wintertime, the forklifts are kept in the laboratory that affect the working area there. Moreover, the woodchips should be warmed up and dried before being used.

Furthermore, there are a few containers in the yard, and if the manager decides to keep them, they can also be used as storage. For instance, the empty pallets, can be kept there, and besides, it is possible to use them as reserved storage.

### 5.2.1 Warehouse Location 1

As can be seen in Figures 7 and 8, the first option would be building a large warehouse in front of the laboratory instead of occupying other spaces for storing. The warehouse would consist of two different parts. One part would be a climate and humidity controlled warehouse in which the forklifts and other equipment that are sensitive to cold weather and humidity could be kept. The other part could be a simple tent warehouse for ordinary items that do not require any special conditions. However, providing all the items with a heated warehouse would be the ideal option.

Following are the advantages of the first warehouse location alternative:

1. The warehouse is close to the laboratory, and it makes it easy to move items from the laboratory to the warehouse or vice versa.
2. According to the Head of the JAMK Bio-Economy Institute, a new road is going to be built close to the POKE area, especially for truck traffic to avoid truck's transportation from the parking lot in front of the main entrance. Thus, in this case, trucks can reach the warehouse easily from behind the campus.
3. As mentioned before, there is already a warehouse in front of the laboratory, so that it would be possible to continue constructing a new building besides it. Consequently, some amount of the budget could be saved as there would be no need to demolish or move the current warehouse.

Moreover, there are two options for the access road to the warehouse:

1. One possibility is constructing a new route that starts from the main road and reaches the laboratory (see Figure 7). This road would be in the private use of the JAMK Bio-Economy Institute.
2. The second choice might be using the same road with POKE (see Figure 8). In this case, there would be no need for a new route construction. However, the traffic and congestion might be high as both institutions use one road.



Figure 7 Warehouse location 1.a



Figure 8 Warehouse location 1.b

### 5.2.2 Warehouse location 2

Another option would be locating the new warehouse on the other side of the road in POKE's area (see Figure 9). There is the probability that POKE would not accept it but there would be another possibility to construct the building (warehouse) in cooperation with POKE. Hence, the warehouse would be in use of both JAMK and POKE.

This option could benefit JAMK in the following ways:

1. The warehouse would be absolutely close to the road and trucks can conveniently reach it without crossing the yard.

2. It is also close to the JAMK laboratory, but it is further comparing to first option, and it is not in sight of people who enter the institute. Alternately, the area in front of laboratory could be used as a parking place. Additionally, it could be decorated with plants and flowers. Moreover, the current solar system, which is close to the main parking area, could be be moved to this new location.



Figure 9 Warehouse location 2

### 5.2.3 Warehouse location 3

Another alternative location for the new warehouse would be behind the main current parking area. Comparing to the two other options, authors sees this option the least probable one, yet it could be considered as a suggestion.

Now, there is a wide land behind the parking area, in which there is enough space to locate a new warehouse. If it is decided to have the warehouse in this location, then it is required to continue the new road, which crosses the POKE's area and continues in front of the JAMK's laboratory, to reaches the warehouse. There is this possibility to consider two gates in the warehouse. One of them is connected to the main road and the second gate is connected to the new road, which crosses the yard in front of the laboratory. However, it is possible to have only one gate if there is not much traffic in the warehouse.

The main advantages of this option would be:

1. It would be close to the main road and it can be accessed easily. However, a new road should be built which connects the main road to the warehouse.
2. There would be more possibilities and flexibilities in choosing the preferable sizes and layout designs for the warehouse as the mentioned area is quite wide and there are no obstacles there.



Figure 10 Warehouse location 3

### 5.3 Warehouse layout design

According to Richards (2011, 159) “the warehouse layout will very much depend on the size and shape of the building, access to it, type of equipment utilized and the operation envisaged.”

In order to being able to compare different alternatives, author decided to provide different options for the warehouse layout design. She also emphasizes that, in warehouse designing, it is critical to recognize the goals, requirements and come to a conclusion accordingly. Some of the warehouses are designed in a way that all the items could be accessed effortlessly in order to have a quicker customer’s services. Although, they might require larger space which means spending more money. On the other

hand, in some circumstances, the most important issue in warehouse layout designing is using the budget and space as effective as possible, while the access to all the items might not be so easy and fast, therefore, the customer service might be at lower pace.

During this project, author has tried to recommend both types of warehouses. In all of the layout designs, it is assumed to have a standard racking system but the size of it could be adjusted according to the requirements and the types of items that would be stored in. Moreover, it is more favorable to store all the items in a heated warehouse although it might be costly. If it would not be possible, the warehouse could be divided in to two sections: heated and tent type warehouse. It is advised to keep the machines in warm place especially, in wintertime.

In the current situation, the woodchips bags are located on the ground in an unheated warehouse. In order to protect the woodchips, pallet collars and pallet boxes are one the best choices to store bulk.

The flexibility in the construction of pallet collars, makes the possibility to store them on a racking system which results in having a more organized warehouse and using the most of the space. Moreover, this kind of packaging is reusable, long-lasting and easy to handle. (see Figure 11, 12, and 13). (KRONUS Carrying Your Business: pallet collars 2018.)

The size of pallet collars is adjustable and they could be set in different heights. This feature makes the transportation process much easier as the packaging could be changed based on the dimensions of an item. (SAVOPAK: easy and flexible packing with pallet collars 2014)





Figure 11 Pallet collars



Figure 11 Pallet collars



Figure 12 Pallet collars

### Layout planning procedure

As it was mentioned in table 1, all the items that must be stored in the warehouse have been provided with their measurements. At first, items' shape, size and need for especial condition are analyzed. Then it is noteworthy to consider if any of cited items can be stacked or placed in a racking system. Besides, it is essential to consider proper material handling tools, the amount of space they occupy and the aisle width, each of them requires.

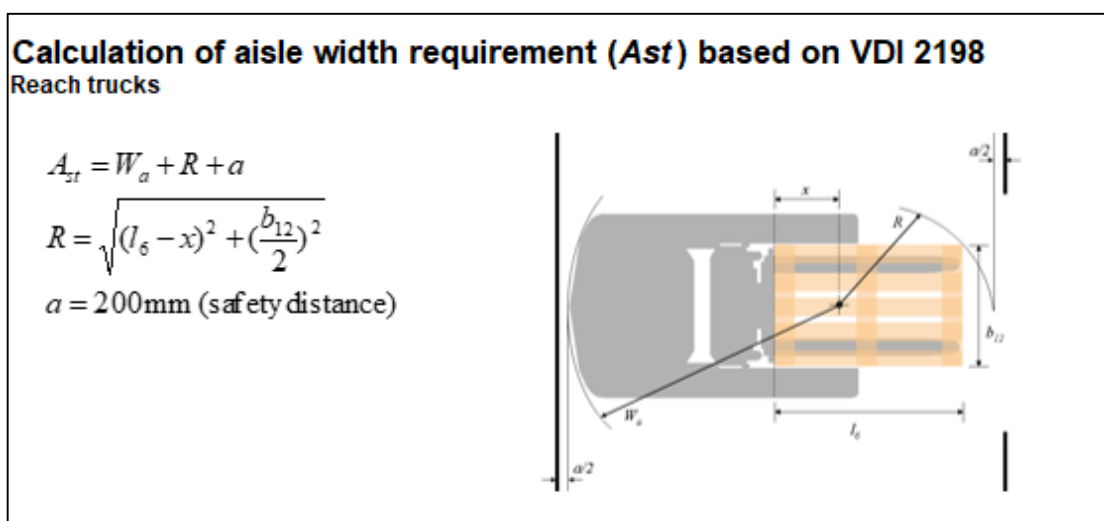


Figure 13 Aisle width calculation ( $A_{st}$ ) based on VDI 2098

Insert data below to calculate $A_{st}$	
Safety distance (mm)	200
Turning radius, $W_a$ (mm)	2609
Pallet/load length, $l_6$ (mm)	1200
Load distance, $x$ (mm)	500
Pallet/load width, $b_{12}$ (mm)	800
Aisle width requirement, $A_{st}$ (mm)	<b>3616</b>

Table 2 Aisle width required at JAMK's warehouse

As it can be noticed in table 2, according to the size of the forklift trucks used at JAMK, a suitable aisle would be around 4 meters wide. Table above (see table 2) shows how the aisle width has been calculated based on the formula presented by The Association of German Engineers (VDI).

All the warehouse dimensions are estimations and they might be adjusted when the final plan is applied.

### 5.3.1 Warehouse layout design 1

In the first option, it is assumed that both shipping and receiving gates are located in same side of the warehouse, which makes the security much easier. However; traffic might be high if both gates would be busy.

The warehouse area has been divided in three different parts. (See Figure 16) The first area that is close to the gates, is suitable for fast-moving items, comparing to other items, as a result they can be picked and handled more easily. This area would be suitable for storing both JAMK and the customers' boilers and woodchips bags. Since, they are used for testing quite often. In addition, the boilers are so heavy and it is better to locate them close to the door in order to prevent long distance movements in the warehouse.

The second area has been designed for medium used items and it is a little bit far from the gates. In this part, the equipment that are used less often, can be stored. The third area is considered for the least used items such as empty pallets or some of the machines that are used hardly. Moreover, it can be used as reserved storage.

All the warehouse layout designs that have been offered in this paper, include a separate area for value adding operations. This area could be used for making some changes in the products, repairing and maintenance. In order to use the most of the warehouse space, any area with low height should be assigned to the value-adding operations and the items picked frequently. Besides, mezzanine floor could be an optimal option as well (see Figure 15). (Richards 2011, 160)

Mezzanine floor is a floor with a ceiling built in the middle of two floors in the shape of a balcony. Therefore, it is not counted as a complete floor. Mezzanine floors could

be constructed in one or two levels depending on the space available and requirements. (What is a Mezzanine floor? 2018) (Richards 2011, 160)

In addition, the area close to the gates has been assigned for consolidation and sortation activities, which is useful if there would be a combined shipment. Moreover, it would be nice to consider having the staff offices as well as a rest room in the warehouse.



Figure 14 Mezzanine floor

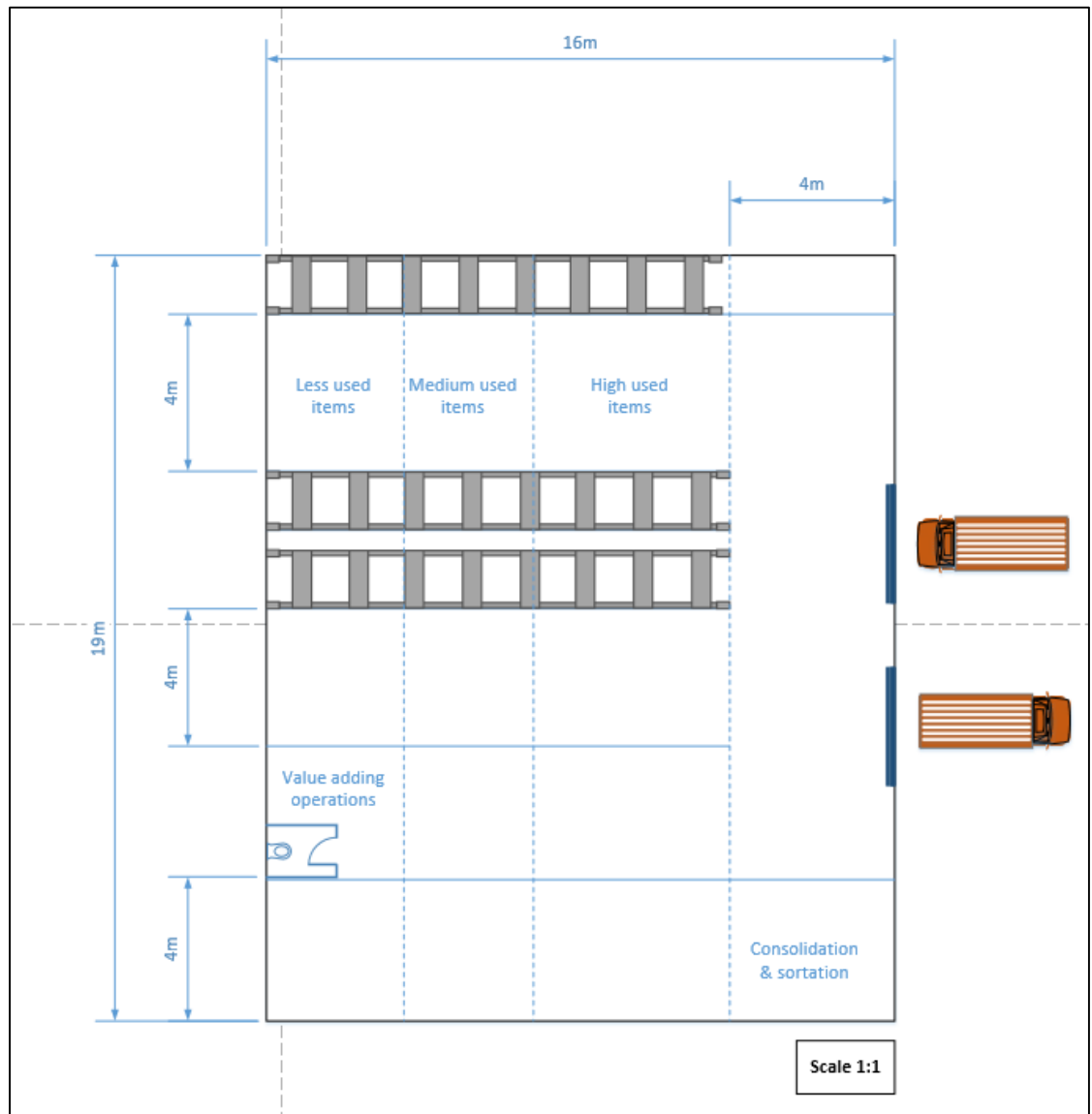


Figure 15 Warehouse layout design 1

### 5.3.2 Warehouse layout design 2

In the second alternative, it is presumed that shipping and receiving trucks are served in opposite sides of the warehouse, this type of warehouses is called, through-flow warehouse.

As Richards (2011, 161) mentions, having two gates in the warehouse would be a suitable option especially if there would be high traffic as the congestion is divided in to two areas. On the other hand, the security issue becomes more challenging when the number of gates increases. Moreover, having two doors in the warehouse might limit the future plans for enlarging the warehouse.

There is a wide aisle in the center of the warehouse where forklifts can move easily. As it can be seen in the picture, the warehouse is divided into six different sections (see Figure 17). It is more logical to place frequently-used products closer to the aisle, as they can be accessed more simply.

Based on author's opinion, using pallet collars is an effective way of storing woodchips bags. Accordingly, two to three collars can be placed on top of each other and which results in saving a lot of space. Besides, pallet collars can be easily moved by the help of the forklifts or other lifting equipment such as pallet jacks. (Michael G. Kay 2012.)

In all the suggested warehouse layouts, it is considered to have a standard racking system for the items that can be put on pallet. In addition, the racking system could be used for storing boxes. The boxes that contain frequently-used items, should be placed in the lower shelves and the upper shelves could be assigned for reserved storage.

For storing large and less frequently-used items and machines, drive-in racking could be considered as an appropriate option (See Figure 18). One kind of pallet racking systems is Drive-in rack which consists of column, row and depth. In Drive-in rack, there is an aisle which fits the size of the forklift and an entry point. Therefore, the worker should drive in to the racking system from one side which would be the entry point and the pallets are taken out from the same side. In Drive-in rack, it is vital to apply an accurate plan for picking items as it follows LIFO (Last-In, First-Out) method. Consequently, the last component placed in the racking system, should be removed first. This issue might be challenging especially in storing perishable items. Although, this problem could be solved by using drive-through racking. The structure of Drive-through rack is the same as Drive-in rack, unless, in Drive-through racking system the items could be accessed from both sides of the racking, as it follows FIFO (First-In, First-Out) system. Consequently, the first item placed in the racking system from one side could be removed as the first component from other side of the racking system. As the result, the throughput increases. The cost of installing these racking systems is low and they are suitable options to use the space efficiently. (M Z Hadi, T Djatna, & Sugiarto 2017.) (Racking systems and warehousing equipment. The backbone of internal logistics.)

Same as the former layout design, there are places for value adding operations, consolidation and sortation.

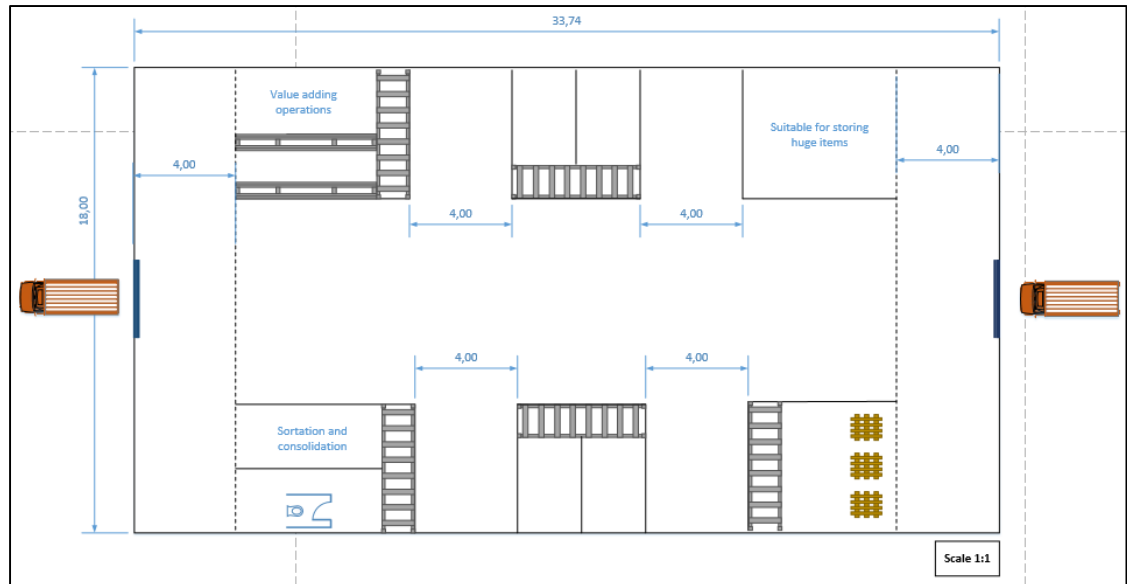


Figure 16 Warehouse layout design 2



Figure 17 Drive-in racking

### 5.3.3 Warehouse layout design 3

Perhaps this option would not be the most cost effective one, as it requires a large area. However, every single item could be accessed easily. As it can be seen in the following warehouse layout design, the shipping and receiving gates are separated. It is recommended to place the most frequently-used items close to the aisles and the gates in order to pick them more conveniently and in a shorter time.

As it was mentioned before, the size of the racking system is adjustable. The author thinks that one of the simplest way to have an organized warehouse is using pallets for storing the items instead of placing them separately. Furthermore, the racking system could be used for storing different kinds of boxes as well.

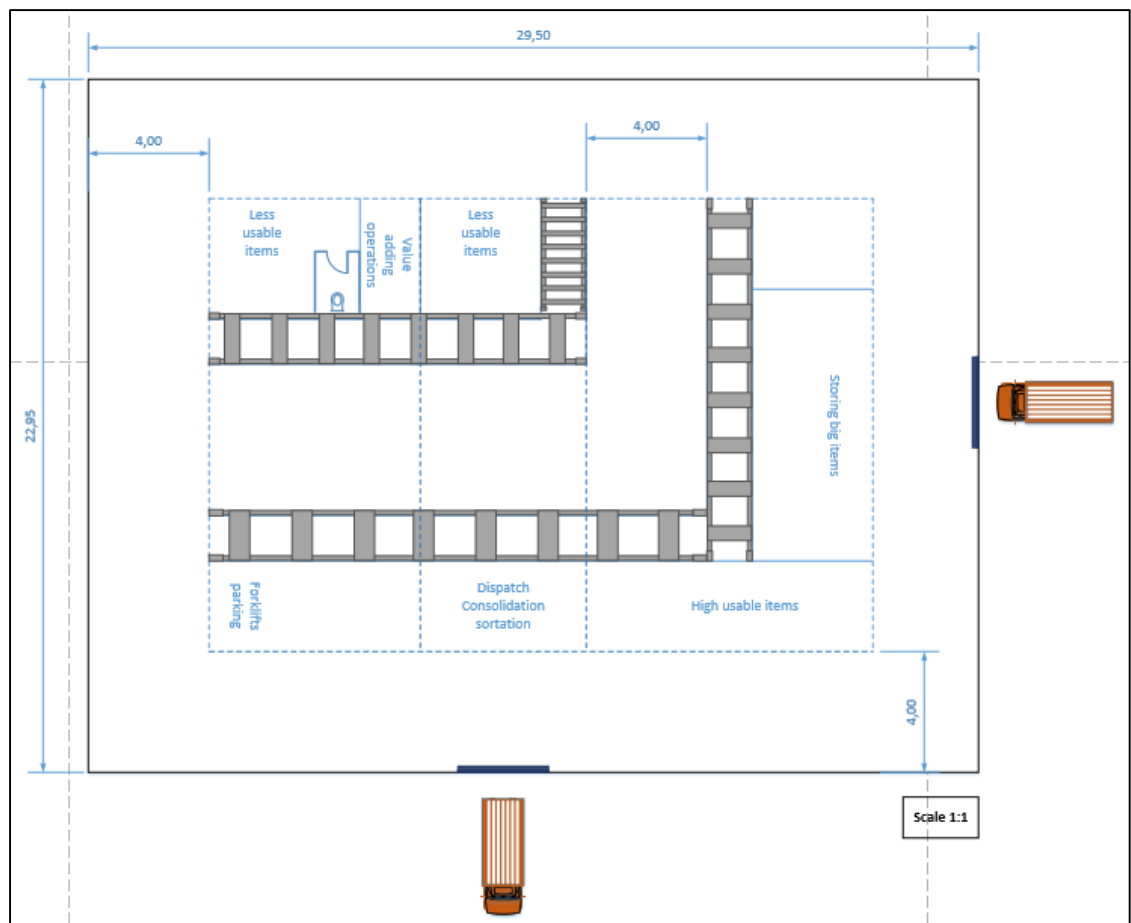


Figure 18 Warehouse layout design 3



### 5.3.4 Warehouse layout design 4

A simple-designed warehouse has been suggested as the fourth alternative. This warehouse has a wide aisle in the center and an aisle, which connects to the exit gate. All the items can be reached through the main aisle. Moreover, it is more logical to place the frequently-used items close to the gates. As it can be noticed in the picture (see Figure 20), the items that are used less frequently, are stored in the middle of the warehouse and the least frequently-used components are located far from the gates. As well as the other layout designs, it is assumed to have a section for consolidation and sortation and a separate area for value adding operations.

There is this possibility to use the JAMK's existing warehouse and build a new warehouse beside the current one. Accordingly, there should be a connecting path between the warehouses for easier access.

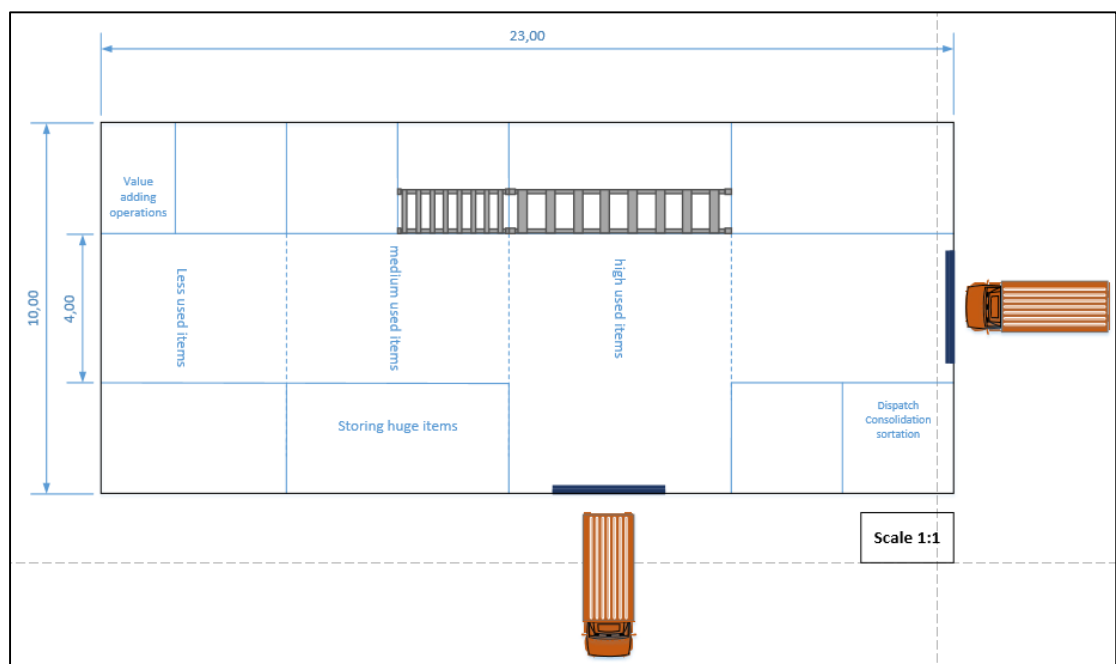


Figure 19 Warehouse design 4.a

The warehouse layout designs that have been proposed in figures 21 and 22, include the same features as in layout design 4.a (see Figure 20), the only difference is one of the gates has been eliminated and only one door is used for both shipping and receiving items (see figures 21 and 22). If only one gate would be used in the warehouse, then the appropriate location of it depends on the direction of truck path.

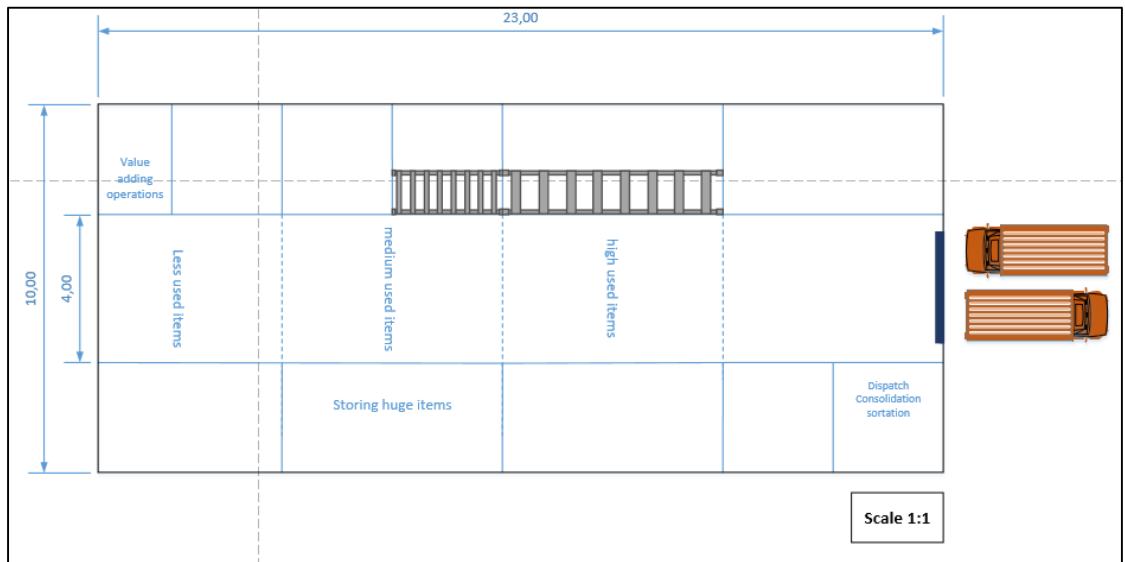


Figure 20 Warehouse design 4.b

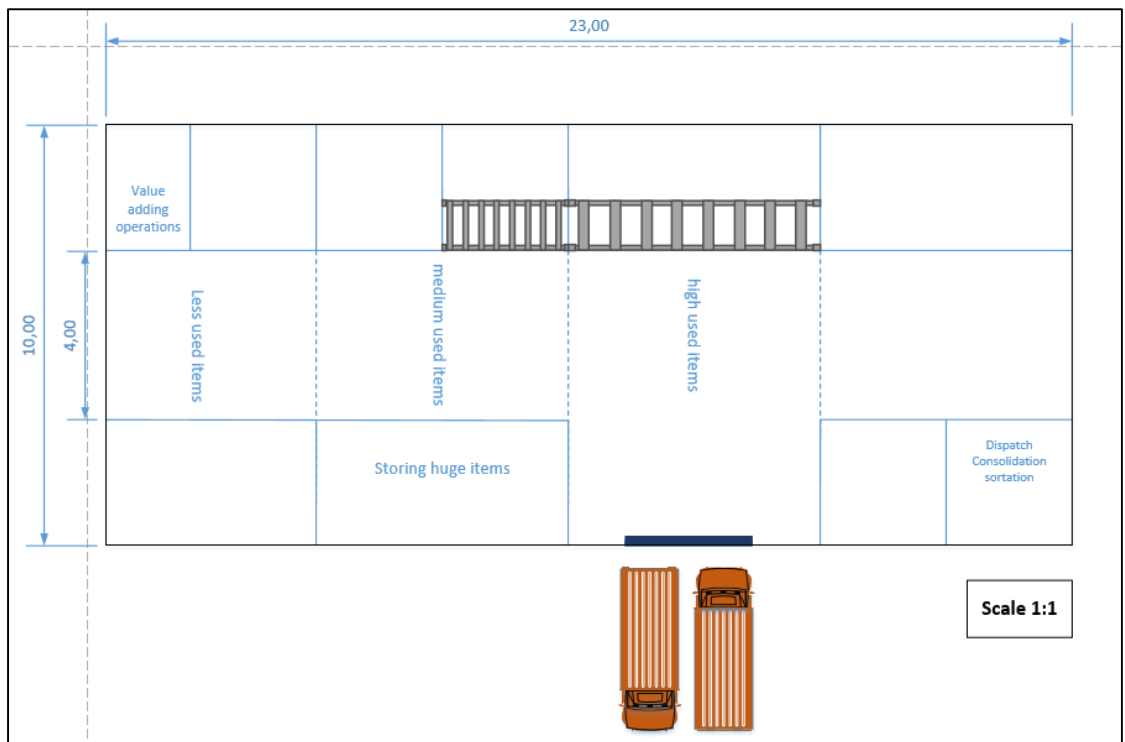


Figure 21 Warehouse design 4.c

## 5.4 Warehouse addressing system

In order to have an organized warehouse, it is vital to plan and apply an addressing system. Addressing system means, using numbers or letters to define each item's location. In the lack of addressing system, a considerable amount of time is wasted for finding different items. Relying on people's memory works well when there are not much items or the workers are not changed or substitute in the warehouse. Therefore, providing a simple and easy addressing system can improve the work efficiency and shorten the reaction time to the customer's need. Addressing system can differ based on the warehouse design and manager's preferences; thus, there is not a solid formula for planning warehouse-addressing system.

Below there are some suggestions for addressing the racking system at the warehouse of JAMK Institute of Bio-Economy.

1. As it can be seen in the picture (see figure 23), two rows of racking are stick together. Additionally, there is a space between every two columns and there is an aisle in front of the racking system.

This addressing system includes five different parts.

- I. First of all, the aisles are identified by letters for example, aisle A. It is also possible to use numbers for identifying the aisles.
- II. Secondly, it is possible to split the warehouse into different sections, however it is totally optional. Section means that all the related items are kept together in one area. Besides, sections can be categorized by numbers such as 01. Another probability would be using alphabets. For example, all boxes are stored in one place together; therefore, that section can be named as "Bo".
- III. The next classification relates to the rows in the racking system. Each row is identified by a number like 01, 02,.. .
- IV. In each racking system there might be several levels, therefore, it is important to describe each level individually. Accordingly, numbers can be used for classification. Depending on the size of the racking system, the numbers can start from 1 or 01.
- V. The last but not the least is diagnosing the location of each item. Usually, in each level every item is numbered from left to right. Here item refers to a pallet, a box, a single element or a component.

To clarify the described numbering system, below is an example (see Figure 24, marked in blue):

Address: A-01-01-4-2

- I. A: aisle A
- II. 01: section 01
- III. 01: row number 01 located in section 01
- IV. 4: fourth level of row 01 in section 01
- V. 2: the item location in fourth level of row 1

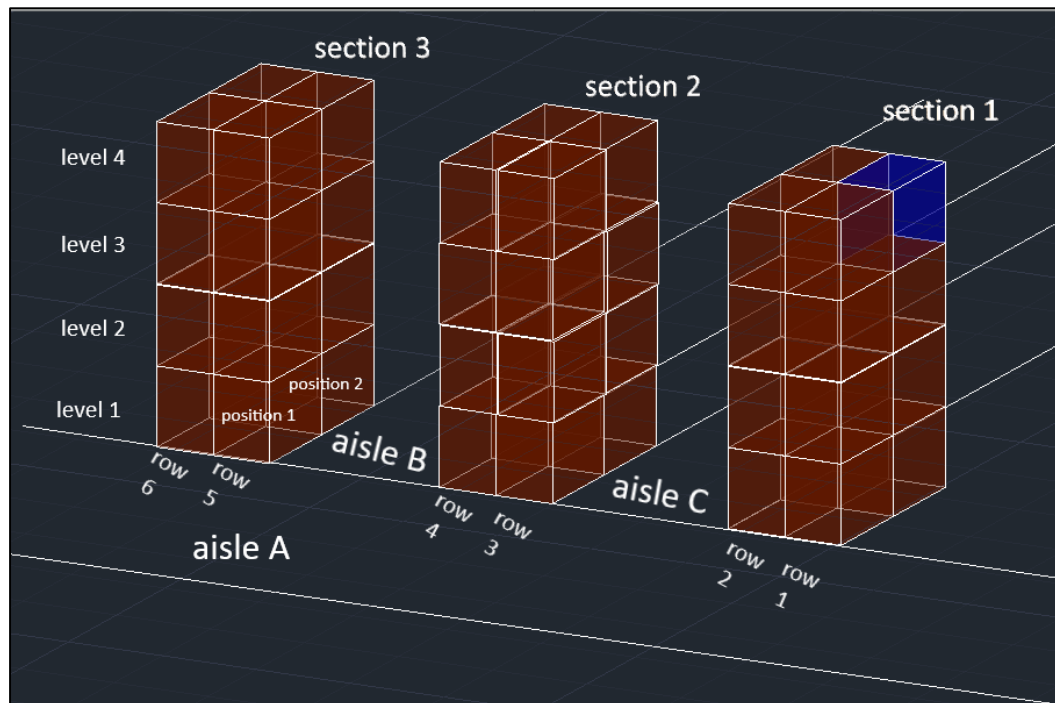


Figure 22 warehouse addressing system

2. As it can be noticed in Figure 24, the racking system can be set in another order. The addressing system would be the same as former example and the only difference is each level is occupied by only one pallet. Consequently, there is no need to have the last part of addressing system, which defines the item's location.

To clarify this numbering system, below is an example (see figure 25, marked in blue):

Address: A-01-04-2

- I. A: aisle A
- II. 01: section 01
- III. 04: row number 4 located in section 01
- IV. 2: second level of row 4 in section 01

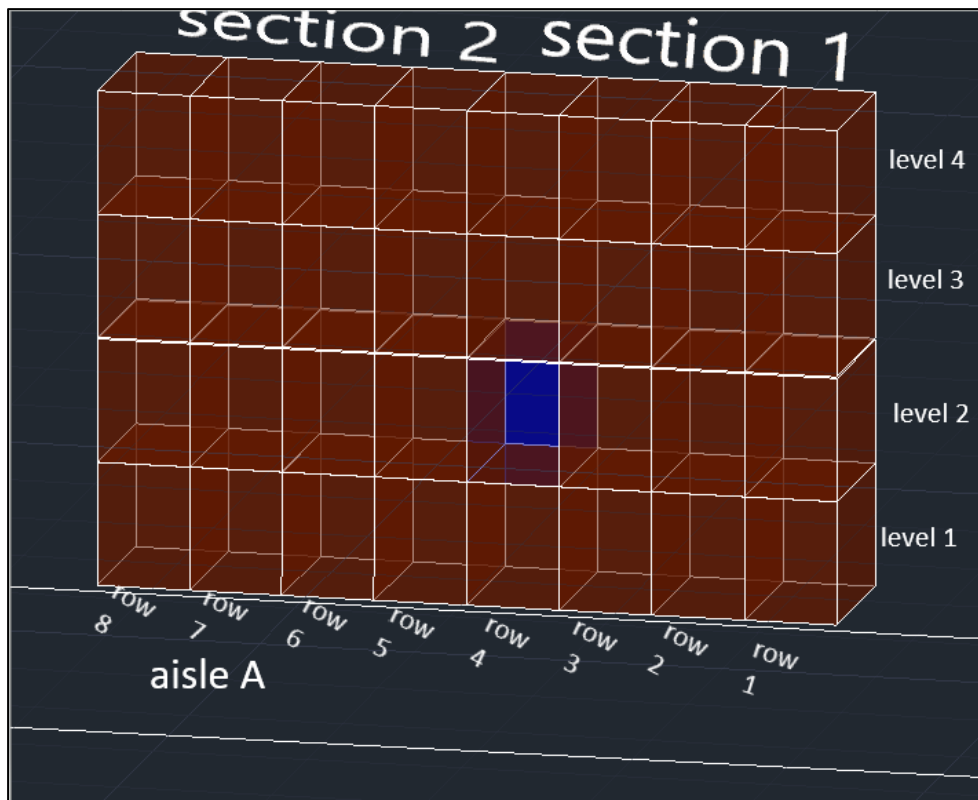


Figure 23 warehouse addressing system

It is vital that all the staff and employees be committed to the categorizing system, otherwise, in a short period the organization will be in jeopardy. As a result, every now and then, a considerable amount of time should be spent to reorganize the items which causes both wasting time and money.

### 5.5 Status after the author's recommendations

Author expects that, discarding all of the unnecessary and obsolete items would clear up the yard which does not have a nice view at the moment. Eventually, the first result would be having an acceptable look. In addition, having a proper and coordinated

warehouse, has a considerable impact on increasing the staff performance that results in serving the customers quicker and more efficiently. Moreover, a lot of time could be saved by stopping reheating the woodchips and moving the machines between the warehouse and the laboratory just in order to protect them from cold weather. Moreover, it would be possible to assign a specific space for locating customers' products in the in the warehouse.

## **6 Research result**

In this section, the optimal solution regarding JAMK's case study and the justifications behind this decision are explained.

### **Final design**

Considering both Head of institution's preferences and the author's opinion, locating the new warehouse in front of the laboratory would be the most suitable option as it can be reached conveniently by the trucks and it is close to the laboratory. Moreover, the truck traffic would not affect the area in front of the main entrance (see Figures 25 and 26). Given the warehouse layout designs, the fourth alternative was selected as the ideal option since the space has been used as efficiently as possible and all the items could be accessed easily.

Below, there is the final version of the warehouse layout design that is offered by the author. (see Figure 27). In this design, all the items and equipment that are required to be stored in the warehouse, have been dedicated with their own space in the building. As it can be noticed in the picture, the addressing system has been applied as well. In the JAMK's case study, almost all the items should be located separately because of their special shape. Therefore, it is not possible to benefit from stacking components on top of each other. Moreover, most of the elements are not suitable to be stored in the racking system, hence, the height of the warehouse could not be used completely.

As it is clarified in figure 25, the warehouse has been divided in to 15 different sections, even numbers are in the right side of the warehouse and odd numbers are in the left side of the warehouse. This division is mainly made based on three elements: the shape and size of the component, how frequently every item is used and efficiently

space utilization. Accordingly, sections 5, 11, and 13 have been distributed into smaller sections. In section 12, it is assumed to have a racking system for storing the items that can be located on pallets, small boxes and empty pallets.

It is suggested that the items which are used more frequently, should be placed close to the gates and less frequently-used items in the middle and the least frequently-used items at the end of the warehouse.



Figure 24 Final warehouse location a



Figure 25 Final warehouse location b



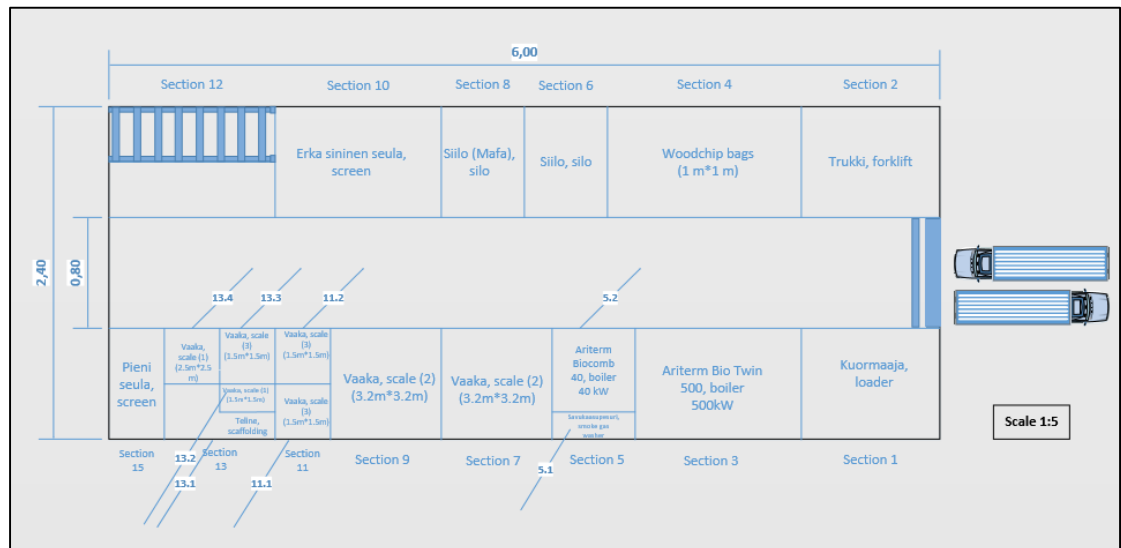


Figure 26 Final warehouse layout design

## 7 Further recommendations

In this section, few development ideas are offered in order to enhance the condition at JAMK's warehouse.

1. First suggestion would be enlarging the warehouse, which means considering a reserved storage for future activities or increasing in the number of customers. It is logical to have an estimation about future plans and changes before constructing the new warehouse. Consequently, the possible upcoming risks could be handled and dealt with more conveniently.

Given the area available in front of the laboratory, it is more probable to extend the length of the warehouse than increasing the width of it (see Figure 28).

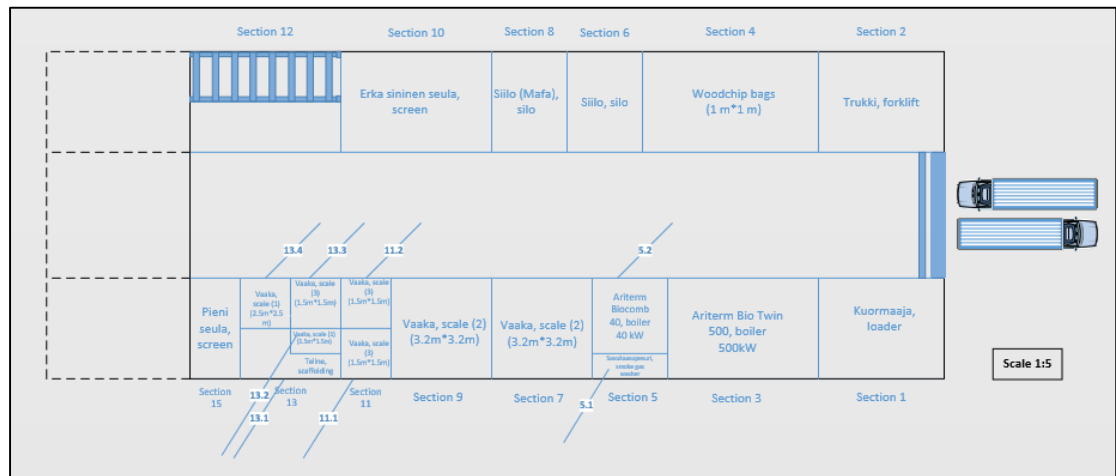


Figure 27 Final warehouse layout design (considering enlargement)

- Second advice would be investing in new forklift trucks which are smaller in size, such as (very) narrow aisle trucks, as a considerable amount of warehouse space is occupied by the very wide aisles. Moreover, smaller forklift trucks provide more flexibility for designing different warehouse layouts.

The price of narrow aisle forklift trucks very much differs based on the model, brand, lifting height and capacity, however, it costs at least 5000 euros.

As it was mentioned in the aisle width calculation chapter, the forklift trucks used at JAMK's warehouse require an aisle which is between 3.5 to 4 meters wide, however, sufficient aisle width for narrow aisle forklift trucks would be between 2.8 to 3.4 meters. Consequently, by using narrow aisle trucks, it would be possible to save up about 18% of space.

Although, purchasing the smaller forklifts are beneficial investment, they have limited lifting weight capacity. It would be a challenge especially, for moving bulks and heavy items, therefore, all the items' dimensions and weights should be considered before deciding on purchasing any new forklift truck.

## 8 Conclusion

The aim of this project was proposing a new warehouse location and layout which could accommodate all the items that were required to be kept in a proper place in

order to clear up the yard and the laboratory from unnecessary components. By applying the author's ideas, it is expected to have an appropriate campus view. Besides, these changes would result in increasing the productivity and tidiness.

During this project, different research methods and resources were used and at the end of the procedure, three various warehouse locations and four distinct warehouse layout designs were suggested. Finally, the optimal alternative was chosen which meets the projects goals and answers the research questions.

## 9 References

*A Guide to Mezzanine Floors*. 2018. Page on AVANTA website. Accessed on 25 August 2018. Retrieved from <https://www.avantauk.com/what-is-a-mezzanine-floor/>

*B600, Raising performance in Heavy Duty application*. n.d. Page on CESAB website. Accessed on 26 October 2018. Retrieved from <http://www.cesab-forklifts.eu/en/products/4-wheel-electric-trucks/b600>

Baker P. & Canessa, M., 2009. *Warehouse design: a structured approach*. *Euro-pean Journal of Operational Research*, 193, 425-436, Accessed on 18 October 2018. Retrieved from <https://dspace.lib.cranfield.ac.uk/bitstream/handle/1826/3017/Warehouse%20Design-2009.pdf?sequence=1&isAllowed=y>

Bragg S. 2018. *How to write off inventory*. Page on AccountingTools website. Accessed on 2 September 2018. Retrieved from <https://www.accountingtools.com/articles/how-to-write-off-inventory.html>

*Easy and flexible packing with pallet collars*, 2014. Page on SAVOPAK website. Accessed on 26 October 2018. Retrieved from [http://www.savopak.com/savopak/en/long-term-packages/pallet\\_collars.php](http://www.savopak.com/savopak/en/long-term-packages/pallet_collars.php)

Gauriloff, R., 2012. *Identifying problems in the warehouse process, case China*. Master's thesis in Industrial Management. University of Vaasa Faculty of Technology. Accessed on 18 October 2018. Retrieved from file:///Users/mac/Downloads/Gauriloff\_Renja-2012-Identifying\_problems\_in\_the\_warehouse\_process\_\_case\_China.pdf

Grover, V. 2015. *Research Approach: An overview. Golden Reserach Thoughts. International Multidisciplinary Research Journal. 4.* 1-8. DAV College of Education, Abohar, India. Accessed on 15 October 2018. Retrieved from [https://www.researchgate.net/publication/273352276\\_RESEARCH\\_APPROACH\\_AN\\_OVERVIEW](https://www.researchgate.net/publication/273352276_RESEARCH_APPROACH_AN_OVERVIEW)

Halbeisin, D., Segerlund, S. 2015. *Intralogistics: a guide to warehouse planning*. Lund: The Authors and Studentlitteratur. Printed in Poland by Interak.

Kassir, Dr.May. 2014-2015. *Layout Planning, Principles of Industrial Engineering*. Accessed on 10 October 2018. Retrieved from [http://uotechnology.edu.iq/dep-production/branch3\\_files/ch4may.pdf](http://uotechnology.edu.iq/dep-production/branch3_files/ch4may.pdf)

KJ Staff. 2017. *Characteristics of an ideal warehouse*. Accessed on 20 October 2018. Retrieved from <https://krishijagran.com/agripedia/characteristics-of-an-ideal-warehouse/>

McLeod, Saul. 2017. *Qualitative vs. Quantitative Research*. Page on SimplyPsychology website. Accessed on 16 October 2018. Retrieved from <https://www.simplypsychology.org/qualitative-quantitative.html>

Newman, I., & Benz, C. R. 1998. *Qualitative-Quantitative Research Methodology: Exploring the Interactive Continuum*. Southern Illinois University Press Carbon-dale and Edwardsville. Accessed on 15 October 2018. Retrieved from <https://books.google.fi/books?hl=en&lr=&id=xumf1ABFz8cC&oi=fnd&pg=PR9&dq=q>

ualita-ti-ve+and+quantitative+re-  
 search&ots=NF0DGVFQXO&sig=WZRqJhLLG2jX12TGmPEWJXYLTy8&redir\_esc=y#v=on  
 nepage&q=firestone&f=false

O'Byrne, R. 2009. *Warehouse Design – Key Factors to Consider*. Accessed on 20 October 2018. Retrieved from <https://www.logisticsbureau.com/warehouse-design-key-factors-to-consider/>

O'Byrne, R. 2017. *About Warehousing*. Accessed on 18 October 2018. Retrieved from <https://www.logisticsbureau.com/about-warehousing/>

*Pallet Collars*. 2018. Page on KRONUS website. Accessed on 26 October 2018. Retrieved from <https://www.kronus.eu/en/blog/articles/what-exactly-is-a-pallet-collar>

Paloniemi, A. 2014. *Infinite possibilities in bioeconomy*. Page on JAMK University of Applied Sciences website. Accessed on 20 May 2018. Retrieved from <https://www.jamk.fi/en/JAMK-information/jamks-annual-report-2014/infinite-possibilities-in-bioeconomy/>

*Racking systems and warehousing equipment. The backbone of internal logistics*. N.d. Page on the Jungheinrich website. Accessed on 10 September 2018. Retrieved from [https://www.jungheinrich.si/uploads/jh\\_importer/assets\\_product\\_27862\\_en-DE\\_vl\\_\\_\\_download\\_\\_\\_link---1/Complete\\_brochure\\_for\\_racking\\_systems\\_and\\_warehouse\\_equipment.pdf](https://www.jungheinrich.si/uploads/jh_importer/assets_product_27862_en-DE_vl___download___link---1/Complete_brochure_for_racking_systems_and_warehouse_equipment.pdf)

Raftery, K. 2016. *Strategies to Reduce HVAC Use in Warehouses*. Page on SmartWatt website. Accessed on 24 May 2018. Retrieved from <https://www.smartwatt.com/strategies-to-reduce-hvac-use-in-warehouses/>

Richards, G. 2011. *Warehouse management: a complete guide to improving efficiency and minimizing costs in the modern warehouse*. London, Philadelphia, New Delhi. KoganPage

Rosinska, M., Chillara, N. 2017. *Layout Design Planning of a Logistics Center*. Master of sciences thesis. Chalmers University of Technology. Department of Technology Management and Economics Division of Supply and Operation Management. Goteborg, Sweden.

*Statistics report for the Logistics industry (road haulage and warehousing), 2009/10 to 2013/14 p (provisional)*. 2013/14p. UK Health and Safety Executive Accessed on 29 August 2018. Retrieved from <http://www.hse.gov.uk/logistics/sic2007.pdf>

*The Tarvaala Bio-Economy Campus is developing*. 2014. Page on JAMK University of Applied Sciences website. Accessed on 20 May 2018. Retrieved from <https://www.jamk.fi/en/JAMK-information/jamks-annual-report-2014/the-tarvaala-bioeconomy-campus-is-developing/>

Tompkins, James A., White, John A., Bozer, Yavuz A., Frazelle, Edward H., Tan-choco, J.M.A., Trevino, Jaime. 1996. *Facilities Management*. Canada: John Wiley & Sons, Inc. 2nd ed.

Waters, D. 2003. *Logistics: an introduction to supply chain management*. Houndmills, Basingstoke, Hampshire, New York: Palgrave Macmillan

*What's the difference between temperature-controlled and climate-controlled storage?* 2018. Page on Suddath website. Accessed on 20 May 2018. Retrieved from <https://suddath.com/about-us/blogs/november-2015/what%E2%80%99s-the-difference-between-temperature-control/>

Wedawatta, G., Ingirige, B., Amaratunga, D. 2011. *Case study as a research strategy: Investigating extreme weather resilience of construction SMEs in the UK*. University of Salford, Manchester. Abstract. Accessed on 14 October 2018. Retrieved from [http://usir.salford.ac.uk/18250/1/6\\_Wedawatta\\_Case\\_study\\_as\\_a\\_research\\_strategy\\_Investigating\\_extreme\\_weather\\_resilience\\_of\\_construction\\_SMEs\\_in\\_the\\_UK.pdf](http://usir.salford.ac.uk/18250/1/6_Wedawatta_Case_study_as_a_research_strategy_Investigating_extreme_weather_resilience_of_construction_SMEs_in_the_UK.pdf)

Zaky Hadi, M., Djatna, T., Poniso, S. 2018. *A modeling of dynamic storage assignment for order picking in beverage warehousing with Drive-in Rack system*. IOP Conference Series: Materials Science and Engineering, 1-2. Accessed on 28 August 2018. Retrieved from <http://iopscience.iop.org/article/10.1088/1757-899X/337/1/012020/pdf>