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Abbreviated Title	Warehouse facility plan for ICM INDUSTRIES
Keywords	Facility planning, Warehouse operations, Optimise, ABC Analysis, Systematic, Utilisation, Space and Stock list.
Abstract	ICM Industries' warehouse was disorganised and unsystematic. There was no form of control over stock and its quantities, which led to decreased sales and theft. Thus, an efficient and optimal warehouse layout plan was established in which space, equipment and labour were utilised to store inventory systematically at a reasonable cost. While taking safety, security and the environment into consideration.
Category	Facility Planning
Confidentiality	None

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Abstract

ICM Industries' warehouse currently has no system set in place for the location of inventory stock. Problems frequently occur due to the lack of control over the stock, as there is no stock list available. The employer is unable to identify the quantities and types of stock on hand which causes customer annoyance when a product is sold out or cannot be found. These occurrences impact the company negatively. Order picking is relatively time-consuming and could lead to loss of sale and increases the probability of theft.

The report is divided into four chapters. **Chapter 1,** focuses on the Project Environment and problem at hand. The company as a whole is analysed and the aim is identified. The overall project aim is to establish an efficient and optimal warehouse in which space is utilised and inventory is stored systematically. The approach, scope and deliverables are discussed and made up of four phases to be completed.

In **Chapter 2**, the Literature Review determines techniques, instruments and methodologies that could assist in the understanding of the problem context. Tools such as Lean, SLP, Pareto analysis, Cube capacity, Standardisation and ABC analysis, are researched for a deeper comprehension of warehouse layouts. The warehouse design looks at the requirements of the company and existing warehouse layouts. Flow, accessibility, space, throughput and standards are investigated to be able to implement the most appropriate methodologies when planning. Space will be utilised by making use of fixtures such as shelves and a mezzanine floor will be built next to the second floor. Various programs are also researched to identify the most applicable one for usage.

Furthermore, in **Chapter 3**, the concept design for the warehouse is drawn up and further analysed. Products will be described and categorised according to their specifications, in a stock list drawn up on *Microsoft Excel*, which will be imported into *Quickbooks*. The layout needs to be designed in a way to provide for maximum space utilisation and inclusion for all products, materials and equipment. The dimensions of the warehouse and all its fixtures are studied to find a design that could cater to the required specifications. The design is drawn to scale on *Chief Architect* as a 2D model and serves as the base for the Warehouse Design.

Chapter 4 presents alternative designs, that are compared and assessed to find the optimal layout. Then, using the stock list in conjunction with the ABC Analysis, Systematic layout planning and other tools and standards, the final design is presented. The final design is drawn up as a 2D floor layout and a 3D model, in which the aim of the project will ultimately be achieved.

Lastly, **Chapter 5** confirms validation in the form of implementation. Implementation was shown through a budget, time studies and surveys. The design was brought to life and now forms the base of ICM's facility plan.

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Acronyms

SFP - Strategic Facility Plan
SLP – Systematic Layout Planning
SCAN – Strategic Creative Analysis
SWOT – Strengths, Weaknesses, Opportunities and Threats
SKU – Stock Keeping Unit

Chapter 1
Project Overview

1.1 Project Environment

The project for ICM Industries is defined within the discussion of the company's environment and background. The problem is explored by analysing the causes of decreasing sales, disorganised spaces and time-consuming tasks in relation to facilities planning. Moreover, ICM Industries' facility needs to be planned, by considering the warehouse industry and its operations. Further analysis of the warehouse design and its operation follows.

1.1.1 Company Background

ICM Industries was founded in 1999 by Ben Ashoori and is located in Midrand, South Africa. The company trades in agricultural and industrial machinery in South Africa and neighbouring countries, including Namibia, Botswana, Zimbabwe, Lesotho and Mozambique (Ashoori, 2018). Initially, the company traded on a small scale, a few machines were sold in the owner's home and the company only had one employee. Over time, the company grew exponentially, both locally and internationally, and ICM continues to increase imports and broaden its product spectrum.

Machinery forms a large part of South Africa's economy, as Bell et al. (2018) notes that South Africa continually strives to grow in the manufacturing sector. Machines form part of every business, directly or indirectly, as it is the main source used to produce goods or provide a service. ICM focused on this need and chose to trade in a wide variety of machinery. There are over 600 product types, including egg incubators, motors, pumps, ice-cream machines, popcorn machines and many more, in which ICM deals with. ICM Industries takes pride in their products and have developed customer loyalty by exploring and searching for the latest machinery and adopting cutting-edge technology. Machinery was quite expensive if bought locally, especially if it was based on the latest technology. ICM foresaw an opportunity of providing these machines at reasonable prices in the existing market. In addition, the company continuously keeps up with changing demands by importing distinctive machines unavailable in South Africa. Thereby, increasing sales due to customers having no other supplier options.

Furthermore, ICM functions in sales and the consumer's demands for new and innovative technologies. Farmers and new start-up business owners are their main customers, yet these businesses often do not have much capital, leaving them always on the lookout for reasonable prices set against high quality and reliable products.

1.1.2 Introduction

ICM owns an office for the trading of goods and a warehouse for storage of inventory. The workforce consists of five employees and an appointed manager who directs and controls the activities within the company. However, while ICM's trades are thriving and the company is performing well, the company is having problems with stock control and the facility layout of their warehouse.

The procedure with which machines are imported takes the form of ocean transportation. Imports are from various countries and are carried by ship. The inventory stock is transported in a container that is stationed on a truck and sent either to the office or placed in storage units in the warehouse. The warehouse is located about fifteen minutes away from the office and is located in a residential area. When the shipment arrives, products are immediately placed wherever space is available, since the warehouse has no set layout. The products are not checked against the order form and quantities are unknown. Problems regularly occur as the employer cannot recollect the quantities of the various products in stock stored in the warehouse, due to the absence of a stock-taking list.

The current process of retrieving a product, consists of the employer requesting the employee to fetch the product from the warehouse during work hours. The employee at times cannot find the product easily, this causes the customer to wait for long periods of time, which makes them frustrated and discouraged to make the actual purchase. It is time-consuming for the employees which raises further dissatisfaction amongst customers and the employee. The employee also retrieves the product without recording the transition. This causes confusion, inaccurate stock numbers and imprecise data. Additionally, the employer had noticed that a few of the employees were stealing, however, he was unable to prove this due to lack of evidence. The company experienced huge losses in assets and inventory, hence the need for a sound stock-taking system is crucial.

The company concluded that a new warehouse will be purchased nearby, about five minutes away, and it would be located in a security complex for increased safety measures. Constraints lie in the size of the warehouse, as it is considerably smaller than the previous warehouse. Therefore, efficient planning is required for the facility's design because products can no longer be placed unsystematically or arbitrarily.

The new warehouse was measured and drawn up using a layout CAD software, *Chief Architect*, that accurately displays the dimensions (in mm) of each area. The employer requested that a mezzanine floor level should be built as an attachment to the second level for additional space and that shelving should be placed on both floors. **Figure 1.1**, is a representation of the ground floor level of the new warehouse.

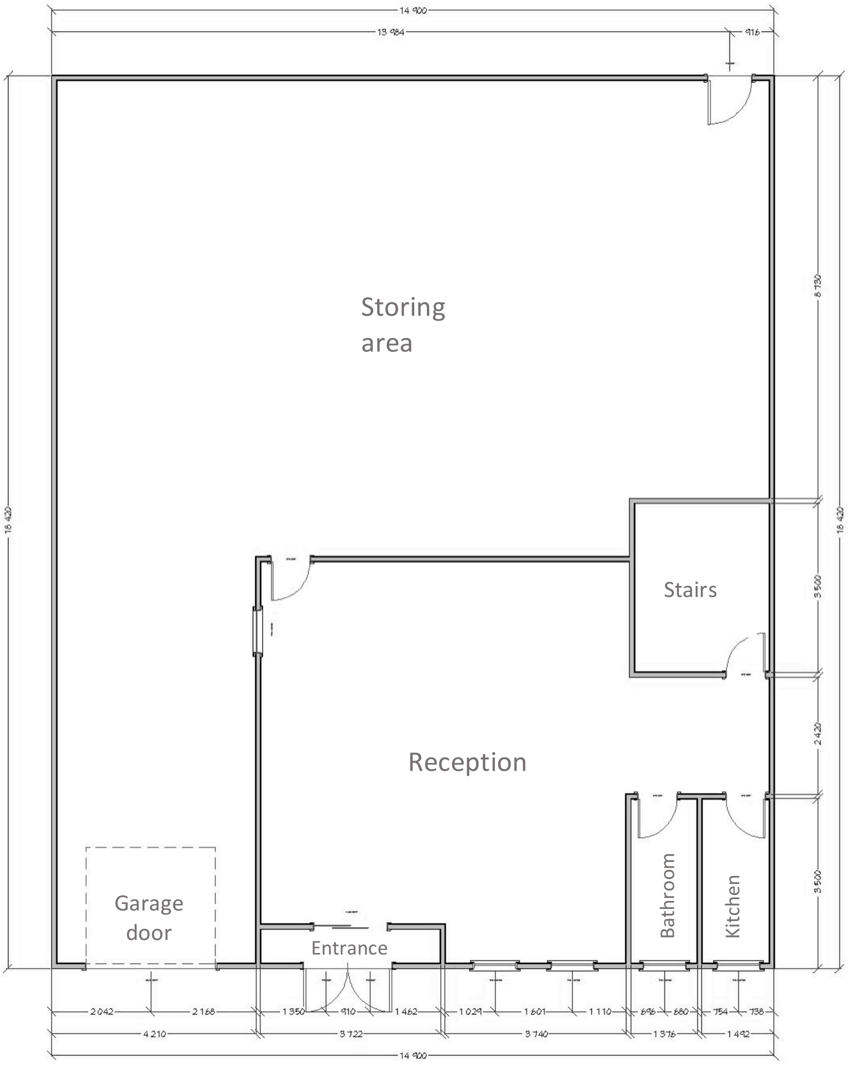


Figure 1.1: Ground level of warehouse plan

Figure 1.2 illustrates the second level in the warehouse. The grey shading indicates the employer’s opinion of where the mezzanine floor level should be placed. This should be examined and validated whether it is feasible or not. And further consulted with a professional to ensure standards are met and means are within budget.

Overall, the problem lies in the unsystematic flow of products. Products are placed arbitrarily, where the employees could find space, therefore making products indistinguishable from each other. The task of retrieving the product is time-consuming and inefficient as employees are confused as to where the product is placed. Customers become frustrated and at times cancel the order if it takes too long or found that the company is out of stock in that product. Profits are lost and sales decrease, as the employer does not know how much stock is available, therefore, is unable to answer customers when asked if a certain product is in stock. The importance of planning the facility is evident in the problems found.

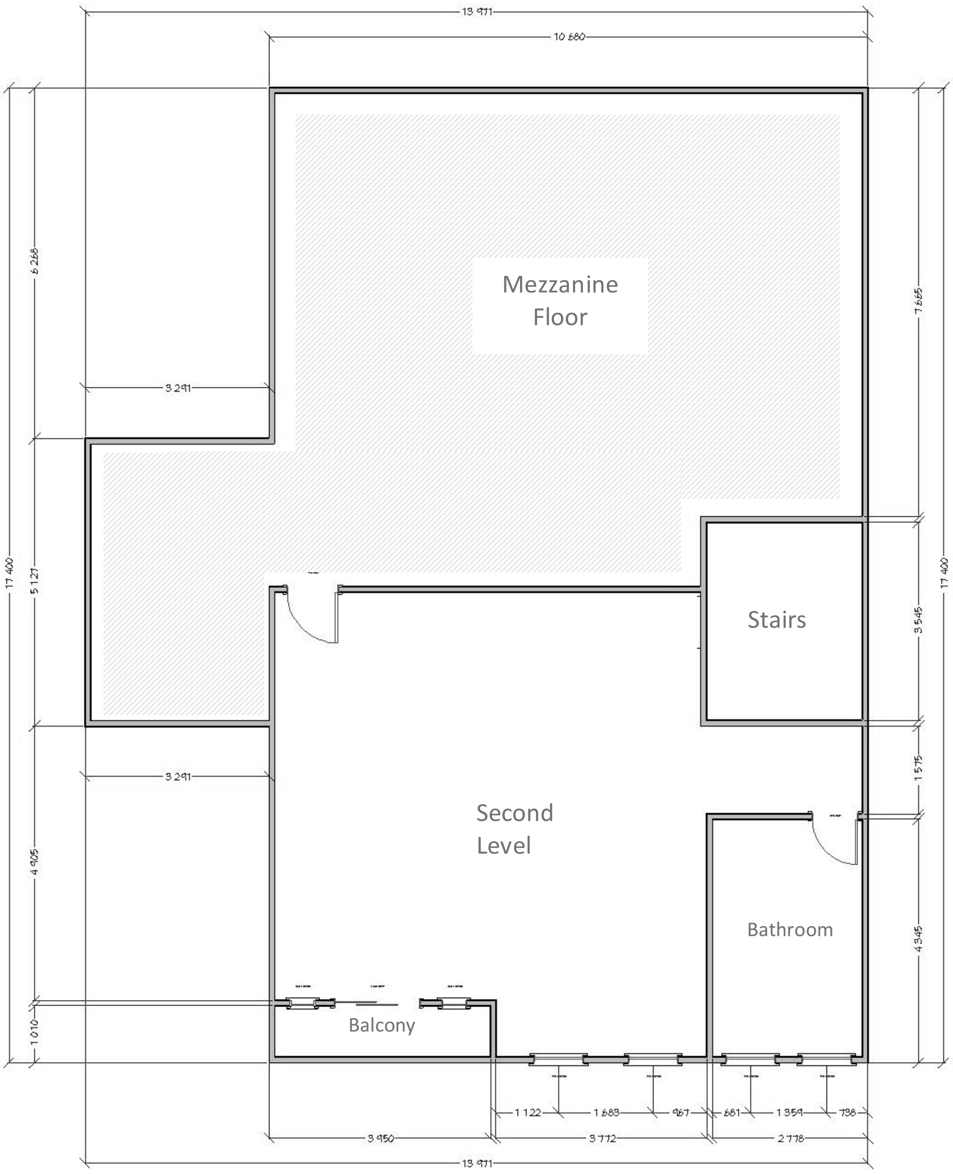


Figure 1.2: Second floor of the warehouse

1.1.3 Facility planning

Facilities are buildings typically developed to produce a product or for a service to be rendered through the integration of materials, machines, equipment and people (Tompkins 2010: 3). A facility could take the form of an office building, university, bank or even a power plant. The layout of the facility depends much on the facility building, the nature of the product, type of industry, type of production process or machinery, the volume of production and product variety. Other factors include the facility environment, its needs and future expansion necessities.

It is essential for facilities to be managed appropriately through effective and efficient planning to be able to achieve the company's goal or purpose. Facilities have analytical characteristics that need to be employed in the design of the plan. These characteristics include adaptability, modularity, flexibility, selective operability, upgradeability and environmentally friendly components. The characteristics need to be used in conjunction with the design requirements of the facility. The requirements comprise of strategic, manufacturing process, workstation and working environment requirements. Therefore, if the analytical characteristics are used while satisfying the design requirements, the goals will be achieved. However, these goals are limited by financial resources such as the product or service cost, the quality and available time and resources.

In the past, Facilities planning was known as a science, while today it is identified as a strategy that provides value and delivers on return on investment. Strategic facility planning (SFP) is a two-to-five plan for a space that is leased or owned and used as a facility (Tompkins et al, 2010). The SFP goals are based on the strategic objectives of the company, that are used to achieve supply chain excellence (Sekula 2009:3).

SFP involves all of the company and stakeholders including engineers, consultants, managers and even the employees. The company needs to select individuals that will be responsible for the planning of the facility as it requires the utmost attention. The facility planners need to focus on the main components of the facility which entails the design, layout, location and the systems within the facility. If all these components are looked at and achieved, it will lead to the improvement of response time and customer satisfaction. As well as, the maximisation on the return on assets and investment (ROA, ROI), integrated supply chains, effective utilisation of resources and improved internal safety.

Furthermore, a facility goes through a life-cycle, in which its objectives constantly change from time to time when improvements are needed. Therefore, facility planning is a continuous improvement process planned to achieve the set-out objectives of the company. A ten-step process, with three phases, is defined by Tompkins et al (2010:18) and presented in **Figure 1.3**, describing ways a facility planning process could be done.

Phase	The Engineering Design Process	The Facilities Planning Process	The Winning Facilities Planning Process
Phase I	Define problem.	1. Define or redefine objective of the facility. 2. Specify primary and support activities.	1A. Understand the organization model of success. 1B. Understand external issues. 1C. Understand internal issues. 2. Establish facilities planning design criteria. 3. Obtain organizational commitment.
Phase II	Analyze the problem. Generate alternatives. Evaluate the alternatives. Select the preferred design.	3. Determine the interrelationships. 4. Determine space requirements. 5. Generate alternative facilities plan. 6. Evaluate alternative facilities plan. 7. Select a facilities plan.	4. Establish teams. 5. Assess present status. 6. Identify specific goals. 7. Identify alternative approaches. 8. Evaluate alternative approach. 9. Define improvement plans. 10. Obtain support for improvement plans.
Phase III	Implement the design.	8. Implement the plan. 9. Maintain and adopt the facilities plan. 10. Redefine the objective of the facility.	11. Implement plans. 12. Audit results.

Figure 1.3: Ten step facilities planning process (Tompkins et al, 2010)

1.1.4 Warehouse industry

Facility planning is crucial in warehouse operations as the planning of a warehouse is being continuously revolutionised. Planning in a warehouse supports the supply chain of the company which leads to the success of the company.

A warehouse is defined as a commercial facility for storage or the accumulation of goods that supports the company's supply chain (Your Article Library, n.d.). Often the definition of a warehouse leads companies in seeing no need for the planning of a warehouse. However, there are many activities involved in getting the goods in and out of the warehouse. Receiving, inspection, postponement, storage, sortation, packing, shipping and quality control are just a few of the activities involved (Tompkins et al 2010:390). Goods are kept and only released once there is a consumer demand. According to Salvendy (2001:1538), the purpose of a warehouse layout is to maximise the effective use of space, equipment, labour and the accessibility and protection of all products stored. This needs to tie in with the most economical layout that will minimise operating cost and provide maximum flexibility to provide for future growth.

The layout of a warehouse is significant when cost, time and efficiency of the operations are in use. Often warehouses are unable to process orders quickly, thus physical distribution and information technology play an important role (Tompkins et al 2010:388). Retrieving orders could be done more effectively by paying attention to warehouse operations. These operations consist of utilising cross-docking and space, increasing value-added services, productivity and order picking operations.

1.2 Project Aim

To plan and design a layout for ICM's warehouse by effectively utilising space, equipment, money and labour while ensuring an optimal, systematic, environmentally friendly and safe way for the keeping of stock.

1.3 Project Approach, Scope & Deliverables

The project was approached in an innovative manner, to prevent past mistakes from occurring. Methods were found for the maximum utilisation of space to be used. The procedure one must follow for the planning of a warehouse layout is an integration of many tools, techniques and methodologies, which consists of four phases.

A flow chart representation displayed in **Figure 1. 4**, illustrates all the deliverables that will be achieved throughout the project that ties in with the approach and scope of the project.

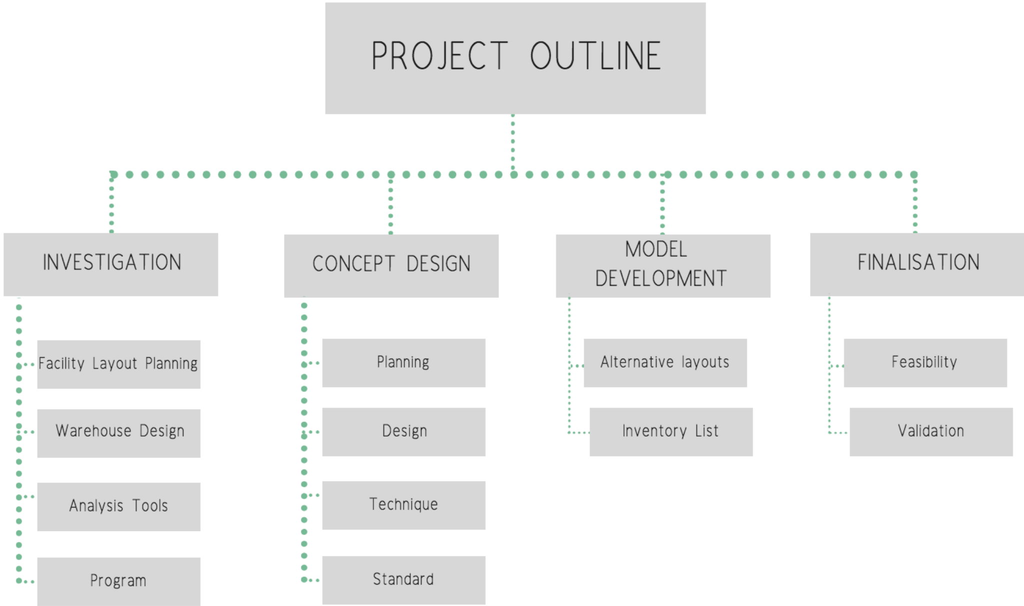


Figure 1. 4: A flow chart representation of the project deliverables

Phase 1: Investigation

All required information and research regarding the project environment was collected and analysed. The information was converted to data in which requirements and constraints were determined in conjunction with a Literature Review. The study established the required tools and techniques needed for the analysis and final design of the warehouse. Phase 1 commences in **Chapter 2** of this report.

1.1 Facilities layout planning: The company's environment was observed and studied, for an accurate representation of available floor space, purpose and goals to be achieved.

1.2 Warehouse design: Product types and various material handling equipment determine the required aisle space, to retrieve or place products from shelves or levels. Problems that existed in previous historical layouts should be avoided.

1.3 Analysis tools: Shelving, *ABC Analysis, Lean, Cube utilisation* and *Standardisation* are several techniques investigated.

1.4 Program: Multiple programs were researched for the completion of the design. Disadvantages and advantages were taken into consideration, and the best-suited program was selected.

Phase 2: Concept Design

Plans regarding the warehouse's requirements, rules and obligations are established in **Chapter 3**.

2.1 Planning phase: The warehouse must conform to the set requirements and constraints the employer has established. Subsequently, constraints were examined to prevent future setbacks from occurring through the use of analysis tools researched in the Literature Review.

2.2 Design phase: The design is carefully thought through and accommodates for shelving and placement of products. Methods and tools were considered when designing the floor layout and products were studied.

2.3 Technique phase: Analysis tools were used for the assignment of products to available storage locations, making it efficient and convenient for the employee.

2.4 Standard phase: O'Byrne (2017) states, the location of receiving and shipping points of the warehouse needs to be established as well as fixed obstacles, such as shelves, stairs, columns should be defined. All regulations were considered during the designing of the warehouse to ensure standards are followed.

Phase 3: Model development

The layouts are assessed according to the set requirements. The stock list was drawn up to be used by ICM in their inventory system. The execution of Phase 3 begins in **Chapter 4**.

3.1 Alternative layouts: Alternate layouts were drawn up, evaluated and compared to determine the final layout that best suits the objectives of the company.

3.2 Inventory list: Inventory stored in the warehouse was studied and an accurate and precise stock list was drawn up. The list gives a detailed description of the product, including all of its characteristics.

Phase 4: Finalisation

The final design is chosen and analysed, whether it is feasible or not. Overall the warehouse needs to be optimal, environmentally friendly, organised, systematic and safe from hazards. The final project is to be completed by the end of phase 4, in **Chapter 5**.

4.1 Feasibility: The layout needs to be easily executed and should have a continual maintenance system in place. Employees should be able to understand fairly quickly how the system works and be able to adapt effortlessly.

4.2 Validation: The final layout design needs to take into consideration safety, environmental conditions, accessibility, efficiency and utilisation of space at a reasonable cost. Validation of the design will be done by analysing implementation through various tests, to ensure the objective of the project is achieved.

1.4 Document Structure

The techniques and tools used to solve the problem were investigated in **Chapter 2**. Various methodologies and steps were researched in the Literature Review, to achieve a successful facility plan for the warehouse. Furthermore, in **Chapter 3,** the concept design for the warehouse plan was drawn up for understand the baseline layout. Later, in **Chapter 4** various designs will be evaluated and compared to find the most appropriate design for ICM's warehouse. A stock list will be drawn to establish the correct placement of the products within the warehouse. Lastly, in **Chapter 5** validation will be achieved through implementation.

Chapter 2
Literature Review

The project relies profoundly on research gathered, which will take the form of a detailed Literature Review. Weatherford (2016), discusses the importance of a Literature Review, as it explores various views, opinions, ideas and knowledge on a specific subject. The study will identify the project environment and determine the tools and techniques that would contribute to the layout planning of the storage facility.

The different methodologies and findings of various authors and inventors will be compared and evaluated. Silyn-Roberts (2000), suggests only relevant information be gathered while other findings should be discarded if false, outdated or irrelevant. By using research as a tool, the probability of success increases since layout models are based off previous layouts and experiences.

The Literature Review will be presented in the form of:

2.1 Facilities layout planning – The overall design of the facility and ways to approach the planning process.
2.2 Warehouse design – All factors involved in the design of the warehouse plan. As well as, system standards that are required by any existing warehouse.
2.3 Analysis tools – Tools that could be implemented to facilitate planning and the designing of the layout.
2.4 Programs – Various programs are compared and evaluated.

2.1 Facilities Layout Planning

In a previous study, Garcia-Diaz et al (2016), defines facilities planning as a plan of action for the physical arrangement of industrial facilities to achieve success in the company's supply chain. In a facility, it is crucial that there is a strong relationship between the working environment, employees, equipment, material and customers. If all these components are used collectively, it will result in an optimised, efficient and well-organised facility. Most companies are unaware that every decision made for the facility will have a direct impact on their needs, assets and objectives. According to Salvendy (2001:1539), these layouts should instil layout philosophies to ensure efficiency and optimisation.

Furthermore, the objectives and goals of the facility need to be analysed and the project environment explored. A tool, known as the SWOT analysis could be applied to analyse the environment and plan for the decision-making process. Kurian (2013:266) states, *S.W.O.T* stands for Strengths, Weaknesses, Opportunities and Threats, and typically takes the form of a four-square template, as shown in **Appendix B**, **Figure B.1**. The breakdown should be done at the beginning of the planning process. All who are involved in the company, including the stakeholders, can take part, as this encourages participation and involvement. The analysis focuses on internal and external factors that influence the businesses facility negatively or positively. Strengths and weaknesses origin internally, factors could be changed however it will require a great deal of effort (Berry, n.d.). In contrast, opportunities and threats are external to the company; these events occur in the market whether wanted or not and cannot be changed. Threats might put the business at risk and should be avoided at all costs.

After identifying the project goals, multiple layouts for the warehouse needs to be designed. A meeting could be organised for the brainstorming of such ideas. Brainstorming is an essential part of planning; it is defined as an informal approach for generating creative designs and solutions to problems in a group discussion (BusinessDictionary.com, n.d.). Issues and problems in the facility are identified and sorted into categories. Participation will increase amongst staff members and employees will feel a sense of involvement in the company's goals. Once having brainstormed ideas, opportunities and problems, it becomes important to identify the reason behind it. An *Interrelationship Diagram*, **Figure B.2**, could be used to describe the cause and effect relationships between the concepts. According to Nancy, (2004:444), the network diagram will identify the natural links between the distinctive characteristics of a complex situation. Areas that will need improvement and problems that occur frequently are identified during this process. Hence, the reason behind the disorganised system of product layout could be identified as its root causes.

At times, the company could get overboard with plans for big ideas when there is in fact limited resources, materials and time. According to Bonacorsi, (2011), *Prioritisation Matrices* are best used for limited problem-solving resources such as money, people or time. The priorities of the different ideas and opportunities need to be established because the key elements need to be completed first before any of the other opportunities are looked at. Hence, there is a need for a *Prioritisation Matrix* that could help decide what is of relative importance. The matrix **Figure B.3**, is created by analysing the relative ability of each possible action to effectively deliver the results required. ICM could use the matrix to establish which ideas should be put on hold and what should be done immediately to enhance the layout of the warehouse.

As discussed earlier, an SFP aids in developing a plan that will be essential for years to come. Nevertheless, companies are continually expanding and changes are emerging. The plan should be re-evaluated to find the best alternative to counteract the changes. According to Tompkins et al, (2010) a successful facility plan should integrate all elements that will influence the company's resources to best support the business goals. These elements include flow, cube space utilisation, flexibility, satisfaction and safety, minimum investment and distance. In the case of ICM's warehouse, additional space could be left for future storage. Additionally, techniques could also be chosen based on their flexibility to adapt to changes. All in all, the facility plan is a detailed description of the requirements to be met and successfully achieved. Further analysis of the warehouse design to be followed.

2.2 Warehouse Design

Facilities exist in many types, warehouses are not purely storage spaces, but analytical mechanisms of companies. Farahani et al (2011) describes the many types of warehouses that exist. The types are based on ownership, stage, geographic area, product type, function, area and system (Farahani et al, 2011). Examples include public warehouses, government warehouses, bonded, cold storage, agricultural, climate control warehouses and distribution centres. In the relation to ICM, the warehouse is of a private one in which finished goods are stored in a $275\mathrm{m}^2$ space. Warehouse designs are based on the physical characteristics and movement of products. According to Rouwenhorst et al, (1998:3) warehouses may be considered as *processes, resources and organisations*. *Processes* are identified as the step products go through when received. All the equipment, material and personnel needed for the operation of the warehouse is known as *resources*. Lastly, the *organisation* is in control of the procedures and planning within the facility. These three concepts should work coherently in the warehouse to establish a well-functioning system for order-picking and product placement within ICM.

Although, Brewer et al (2008), notes that there are challenges that accompany the designing process when associated with a warehouse. Product information is unavailable or uncertain most of the time and high costs are present due to the operations in a warehouse (Rouwenhorst et al, 1998:2). Agreeing, Cotts et al (2010), emphasizes the importance of the warehouse layout, as it could save five to ten percent of typical costs. Furthermore, the design of the warehouse never stays fixed; the market is continuously changing, placing new demands and requirements on companies (Tompkins et al, 2010). The planning and layout of the warehouse is a cycle that should be redone after a specified time period, as shown in **Figure 2.1**. In regards to ICM Industries, it would be preferable if the planning and design were revised every year, as there is limited space and new orders are consistently arriving at the warehouse.

Consequently, there exist numerous design processes for warehouses. However, the theories and techniques used are often similar and normally follow several consecutive phases. According to Rouwenhorst et al (1998), the concept, layout, specifications, equipment, materials and control policies are some of these phases. All these decisions have an impact on a strategic, tactical or operational level (Rouwenhorst et al, 1998:6). Thus, every decision made needs to consider the impact it might make on the various levels. The design chosen needs to minimise the time taken for a product to be retrieved and reduce the material handling time. Tompkins et al (2010) states that a good layout comprises of the optimisation of productivity and space, utilisation of labour and production capacity, and the reduction in handling costs and congestion.

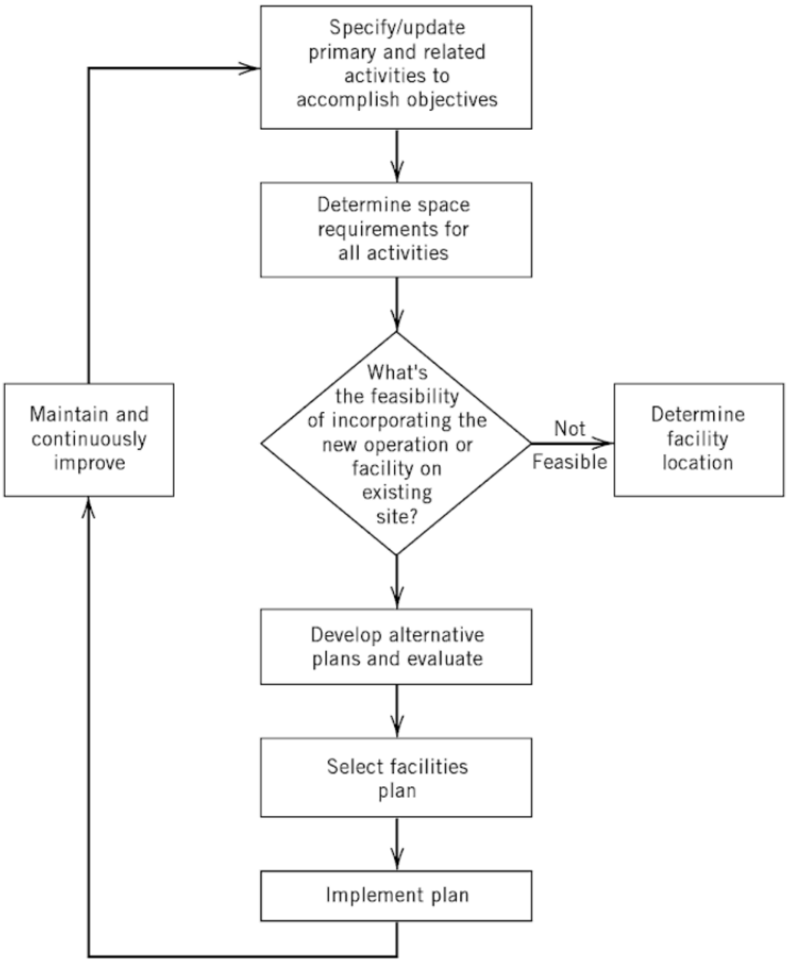


Figure 2.1: Facility designing and planning cycle (Tompkins et al, 2010)

2.2.1 Factors in designing a warehouse layout

In an earlier study, Airdrie (2009) states that four factors are applied when planning or designing the layout of any storage facility. The four factors are known as the pneumonic *FAST*, which stands for Flow, Accessibility, Space and Throughput.

2.2.1.1 Flow

Tompkins et al, (2010) suggests a logical sequence or circulation of operations and products is required within the warehouse. Airdrie (2009), explains that rotation in the warehouse is recognized as how often the product is renewed, leading to a high input and output rate. TZA Consulting (2006) comments further and mentions whenever a product moves in the warehouse, the probability of errors increase. If the flow is not competent, products are not inspected or even go missing, causing problems that could affect profitability. Therefore, a controlled and uninterrupted movement of people, machines and equipment should be existent. The crucial section in the flow process is *warehousing* because here the flow of the layout will affect the picking, packing and the putaway process.

Flow within the warehouse typically consists of the following operations:
(Farahani et al, 2011:186)

- Receiving
  Shipment delivers containers of stock to warehouses, where the stock is off-loaded. When received, all documentation should be checked and verified. Careful planning follows where products are then arranged in terms of characteristics. According to, Tompkins et al (2010), characteristics involve the number of units, product dimension, weight and specification. Farahani et al (2011) states, that if products are related to one another, it should be placed in close proximity to the other. When ICM receives stock, a document is attached to the order. Here all stock can be checked against order amounts and be submitted into the system immediately. Inspection checks should be implemented as part of the process to prevent any incidents. In most cases, random stock is selected and examined if numbers are great.

- Putaway
  Once received and identified, products are transported to their specific storage areas. To ease the putaway process, labelling (*Kanban* - to be discussed later) could be made available for the storage areas and the various types of products. Here, employees should be familiar with the storage sections and product details (Farahani et al, 2011). Additionally, employees should record all transitions taking place to provide accurate data for the system.

- Order Picking
  When the customer orders a product, the process of retrieving the product from the warehouse to fulfil the customer order is known as order-picking (Tompkins et al, 2010). A document should be made available showing the location of the different products. Products that are similar should be placed together and higher probability items should be easily accessible. Farahani et al (2011) identifies various picking methods, including discreet, batch, zone and wave. The different methods require different pickers, lines and periods. It is essential for the company to plan for the next wave of picking in advance to the reduce the time and provide an efficient process flow. In **Figure B. 4**, various picking alternatives are shown. The picking style will be chosen based on the type of product. Most products owned by ICM are packaged in rectangular or square boxes making the picking alternatives such as bin shelving, deep racking, or case flow rack applicable.

- Shipping
  Once orders are picked, they are placed in the shipping areas to be collected and sent to customers. If there are any shortages in stock, it should be noted and brought to the attention of the employer to prevent stock-outs (Farahani et al, 2011). Here, the products are further packaged if necessary and ready for transport. It is of utmost importance to document products leaving and entering the warehouse to ensure the stock list is accurate and up to date, preventing mishaps and miscommunications.

2.2.1.2 Accessibility

Accessibility is significant for fast moving stock with minimum compromise levels (Farahani et al, 2011). Products need to be strategically placed based on an analysis tool. Popular items should be located where employees can access easily and should be close to shipping points. High demand products of ICM should be placed near the collection point or in close proximities, for example, ground level. As this will reduce the order-picking time and prevent confusion.

Moreover, employees are one of the most important assets of the company. The number of employees required, working hours, shits and level of training must be known to establish an organised workflow within the warehouse (Farahani et al, 2011). ICM has quite a small team of employees responsible for this. Only three of the employees will be allowed in the warehouse to retrieve products. Therefore, making it a controllable number of workers in the system, ensuring security.

2.2.1.3 Space

Ensuring accessibility, space needs to be made available. However, determining space is quite challenging, as there are many uncertainties. Uncertainties include the changing assortment of products, changing organizational designs, new technology and varying demand levels (Tompkins et al, 2010). The facilities planner is capable of planning for five to ten years in the future, considering that there are no big changes in the layout (Farahani et al, 2011). Furthermore, *Parkinson's law* states that capacity is filled up sooner than you plan (Fiorido, 2013). Therefore, making it crucial to have a system developed for the planning of the facility.

In regards to the warehouse space design, Tompkins et al (2010) emphasises the importance of storage methods and units, stock levels, strategies, building constraints, supplies and equipment to be studied. According to the study by Airdrie (2009), maximum space is given to operational storage and stock processing purposes and minimum spaces for associated functions such as reception and offices. Additionally, modern approaches are constantly changing the requirements needed for space as opposed to the past (Tompkins et al, 2010). Requirements for space are being reduced because products are condensed into smaller lots and unit load sizes and by making use of decentralised storage areas.

Yet, there are certain limitations that already exists within the warehouse. Windows, boxes, power lines, columns, shelves, floors, ceiling heights are just a few (Tompkins et al, 2010). Building regulations form part of every facility and need to be complied with. Aisle space is one of the crucial regulations that need to be followed as transport equipment could affect the design proposal. Aisle estimates are given in **Table 2. 1** and **Table 2. 2** indicates the minimum requirements required for walk-through or machine travel aisles. ICM is in possession of a forklift, therefore, it should be taken into consideration when determining the aisle widths.

Table 2. 1: Aisle allowances

If the largest load is	*Aisle Allowance (Percentage of Net Area Required)*
Less than 0.557 m^2	5-10
Between 0.557 m^2 and 1.115 m^2	10-20
Between 1.115 m^2 and 1.672 m^2	20-30
Greater than 1.672 m^2	30-40

Table 2. 2: Aisle widths according to flow

Type of Flow	*Aisle Width (m)*
Tractor	*3.658*
3-ton Forklift	*3.353*
2-ton Forklift	*3.048*
1-ton Forklift	*2.743*
Narrow Aisle Truck	*1.829*
Personnel	*0.914*
Personnel with Doors Opening into the Aisle from One Side	*1.829*
Personnel with Doors Opening into the Aisle from Two Side	*2.438*

2.2.1.4 Throughput

Not only should the category of the product be analysed but the velocity of the flow through of products. The study by Airdrie (2009) notes, handling requirements, dimensions, characteristics, products' fragility, safety, flammability, perishability, and compatibility as some of these factors that should be analysed. The velocity determines the volumes of product moving through the warehouse daily. The distance between the shipping, storage and receiving points needs to be examined and carefully calculated. Most of the time there are great numbers of inventory stock because it is not managed or planned properly. Tompkins et al (2010) explains how inventory could be reduced by faster production throughput or smaller batch or lot sizes. The *80/20 rule (Pareto analysis)* could be applied to gain control of the most important products as well as setting a high bar for inventory turnover (Tompkins et al, 2010). It will also, in turn, improve capital productivity for ICM by taking control of stock levels to ensure the warehouse is not over-stocked or under-stocked.

2.2.2 Storage

The type of storage used in the warehouse is determined by the type of product. The product could be a finished, semi-finished good or raw material. Depending on the product, storage types could be block stock, racking, shelf racking, pallet racking, bulk stock, binning, carton pick, loose pick face, unit pick or many other forms (Sonjoy, 2013). As mentioned in the study by Sonjoy (2013), warehouses typically make use of pallet racking on several levels. Warehouses that contain finished goods make use of block stack racking or other dense rack systems. Other storages such as mezzanine store binning and shelving are used for small parts and storage of spare parts (Sonjoy, 2013). ICM could make use of these storage types as it fills the requirements. In **Figure B. 5**, various storage alternatives are shown that could be employed when designing the warehouse. As mentioned, most companies make use of the racking system. The rack design follows the following procedure:

a. SKU Analysis

Physical products in inventory are labelled as Stock Keeping Units (SKU) for identification purposes (Gulati, 2009). It is often set as a barcode that aids in keeping track of inventory. SKUs can be organised into the various categories according to their characteristics. Type, size, volume, shape, weight and movement of SKU are some of these characteristics. The Pareto analysis identifies which SKUs contribute more to sales than others. The movements of SKUs would be identified as fast-moving, slow-moving or other measures contingent on the nature of the company (Sonjoy, 2013). Thus, the SKUs that fall in the 20% range ought to be positioned in the “Priority” zone to aid the employee in the picking process.

b. Defining unit load

After having identified the SKU’s the unit loads should be established. Unit loads differ from one warehouse to another. The loads need to be standardised within ICM and defined depending on its type. Sonjoy (2013) identifies various loads, it could be a 2-way, 4-way, reversible or irreversible unit load. The size could also be industrial or euro as shown in **Figure B. 6**. The unit loads are placed on shelves and these could take the form of wire mesh, flat metal, steel or even wooden shelves.

c. Calculating storage capacity

These shelves can only hold certain capacities and can have limits in height. Storage capacity should be based on the type of location or system used, fixed, random or mixed (Sonjoy, 2013). The maximisation of storage capacity is achieved through the evaluation of the available floor space and the height of the roof or second level. Moreover, the warehouse should utilise the maximum potential of space – vertical and horizontal space. Vertical space could be exploited optimally using cubic capacity. The cubic tool adds additional space rather than just the floor area. Mezzanine floors and carousels are used as cube utilisation and assist in layouts where floor space is at its minimum. ICM could easily make use of cube utilisation because the warehouse has a high ceiling.

d. Flexibility

Tompkins et al (2010) states that planning is essential for unseen future changes that could be detrimental to the business causing high costs in storage. Sonjoy (2013) agreeing with Tompkins et al (2010) explains that it is imperative to have flexible racking systems to minimise congestion and bottlenecks of smooth flowing processes. Not only should the processes be flexible but the way shelves are placed and storage areas identified. Therefore, ICM should preserve additional space for any future changes or unexpected stock levels, to combat unforeseen challenges.

2.2.3 Warehouse system standards

After having established storage types, there are a number of standards that need to be followed. The facilities planner is responsible for specifying what systems are required and how it will be integrated into the overall facility (Tompkins et al, 2010:473). Particular standards for warehouses should also be present when designing the layout of the facility. These factors are as important as the rest of the planning tools as it could make or break the facility.

2.2.3.1 Structural systems

The structural grid spacing, needs to improve the function of the facility especially in a warehouse. The choice of material for structural systems depends on the requirements of the facility. Steel or reinforced concrete skeleton frames are often used in industrial facilities (Tompkins et al, 2010:474). A company might require the material to be strong (steel fails easily due to its brittleness) or that the material should have fire protection (steel loses its strength when heated beyond 1000°F). Whichever, the material used, it will affect the rack dimensions, aisle widths, column spacing, placement of equipment, and flooring for mezzanine levels. ICM requires a strong structural system because most products are large and heavy.

2.2.3.2 Lighting and electrical systems

Secondly, proper lighting is needed in the warehouse, this consists of natural and artificial light. Solar energy could also be used if there is a need for energy concepts in the warehouse (Sonjoy, 2013). Mainly, the need for lighting is for employees to navigate and find the products with ease. Therefore, additional lighting should be installed if needed. Efficient lighting will ease the process of retrieval and provide a well-lit environment.

2.2.3.3 Safety systems

More importantly, employees should be briefed on the general Health and Safety Principles and rules followed in warehouses. The rules could be presented by the manager or by an external individual who is already knowledgeable in the subject at hand. Rules should be detailed in electrical safety, hazardous materials and safety gear used in case of emergencies or incidents (Tompkins et al, 2010). There are various operational safety problems such as fires, chemical exposure, ladders and material handling equipment used throughout the warehouse (Sonjoy, 2013). Signs could be utilised as prevention methods. Visual aids should be employed to ensure proper signage of precautions and hazards.

Furthermore, machines and products are required to be placed in manners that are safe and stable. If this is disregarded, it could cause many problems in the future. Some of the products cannot be stacked on top of one another and others can, this depends on the type. Therefore, maximum heights of stacking and shelving should be investigated (Tompkins et al, 2010). As the safety of the employees should be given full attention. Additionally, the security of the warehouse as a whole should also be one of the main priorities of the employer. Security systems should be incorporated in the designing of the warehouse to reduce theft and misunderstandings. These could include cameras, alarm systems and payment to local security services (Sonjoy, 2013). Systems within the warehouse operation will also have to be secured and accurate. By having the correct documentation for the transitions of stock and having a working stock inventory system, the security will increase and the employer can be at ease.

2.2.3.4 Atmospheric and Thermal requirements

The health of the employees is of great importance to the company. It is essential for the employees to feel comfortable when in the facility. Ventilation systems, such as Heating, Ventilation and Air-conditioning (HVAC) systems or ceiling mounted fans should be installed to provide for air circulation and to reduce heat stratification (Sonjoy, 2013). Though, safety should also be in mind when installing such systems. Fans should be placed higher than the highest forklift level, to ensure the safety of employees. Furthermore, ventilation systems should be placed if certain machines cannot handle the existing temperature of the warehouse. Tompkins et al (2010) describes that thermal performance is needed where the facility requires a different temperature inside the facility than want the climate is outside the facility.

2.2.3.5 Environment

According to Tompkins et al (2010), the facility needs to be kept in order by providing clean working environments. The warehouse needs to be cleaned and maintained often to reduce health risks and incidents. Bins and recycling units should be located around the warehouse to ensure an environmentally-friendly facility. Systems and fixtures, such as motion sensor lighting or solar panels, could be used to save energy in an efficient and harmless manner.

If all standards are followed it will ensure a well-working environment for the warehouse. It will be both ethical and organised. Employees will feel comfortable working there and the process of retrieval and storage would be much easier.

2.3 Analysis tools

The warehouse design is used coherently with the analysis tools, to establish the correct placement of products. The design could be laid out and calculated using several techniques. The facilities planner will need to establish which one will have a greater effect on optimisation and maximum utilisation of space.

2.3.1 ABC Analysis

The ABC analysis is a technique used to manage inventory assets in the categories of A, B, C, A being the highest priority (Rufe, 2013:395). The technique is based on the Pareto analysis, which was developed by an economist in the 17^{th} century (Nyman, 2001:90). Pareto's law proved that most things that are done are not critical. He stated that 20% of the products in inventory is actually involved in 80% of the usage, an example is shown in **Figure B. 7**.

By focusing on the 20%, the company will have control over inventory and costs can decrease overall. Therefore, ABC analysis could be the inventory plan within the facility to establish a degree or level of control over inventory. There are three levels. Category A is usually the highest value, most controlled products which fall within the margin of 0-20% of products. Category B is the good records where not much control is needed which falls between 20-50% of products. Lastly, Category C includes the rest of the products, these products are often low in cost and have limited control. The techniques could use profit, number of items sold, or even size as a factor for establishing the different categories. It all depends on what the requirements of the company are. **Figure 2.2**, shows a typical ABC analysis based on consumption, quantity.

ABC Analysis Template

www.Planning-Templates.com

A = 70% (7 Items) , B = 85 % (6 Items) , C = (37 Items), Total 50 Items

Item	Consumtion Qty	cost/unit	Amount	Acc. Amount	ABC Class
R-005	5,200	320.00	1,664,000.00	1,664,000.00	A
R-041	5,000	200.00	1,000,000.00	2,664,000.00	A
R-036	2,000	325.00	650,000.00	3,314,000.00	A
R-016	2,000	320.00	640,000.00	3,954,000.00	A
R-008	2,500	200.00	500,000.00	4,454,000.00	A
R-050	2,346	200.00	469,200.00	4,923,200.00	A
R-014	1,400	325.00	455,000.00	5,378,200.00	A
R-030	2,000	200.00	400,000.00	5,778,200.00	B
R-025	900	325.00	292,500.00	6,070,700.00	B
R-032	4,500	50.00	225,000.00	6,295,700.00	B
R-024	2,000	100.00	200,000.00	6,495,700.00	B
R-003	450	325.00	146,250.00	6,641,950.00	B
R-009	3,000	44.00	132,000.00	6,773,950.00	B
R-013	1,300	100.00	130,000.00	6,903,950.00	C
R-027	400	320.00	128,000.00	7,031,950.00	C
R-019	600	200.00	120,000.00	7,151,950.00	C
R-010	2,000	50.00	100,000.00	7,251,950.00	C

Figure 2.2: ABC Analysis (Anon, n.d.)

2.3.2 Lean

Lean was established 1.6 million years ago, and later developed by Henry Ford and then improved by Taiichno Ohno, head of Toyota (Eaton, 2013). The reduction of waste and lead times in the facility to redesign a system that is cost-effective, safe and timely (Eaton, 2013). Lean is known for its seven wastages. These wastes are identified as an activity that absorbs time and resources but that does not add value (Mynott, 2012). Wastages include aspects of over-production, defects, over-processing, unnecessary travel and machine time, waiting and inventory waste. Lean applies in the placement of products in a warehouse, as the travelling time for an employee to the desired product should be kept at a minimum. Many tools are based off lean manufacturing which includes *Six sigma, 5S plan, system analysis, Total Quality Management (TQM) and Kanban systems*. It is crucial for the facility planner to take these wastes into consideration when planning the layout of the warehouse.

2.3.2.1 Kanban

Furthermore, Kanban is the Japanese term for signal and was developed by Toyotas businessman Taicho Ohno (Burke et al, 2017). It is an easily understood pull system in the form of 2-bin, 3-bin, top-up or multi-card systems. The signal shows when additional products need to be ordered or shipped (resupply) because product levels are decreasing. Moreover, visual management systems are incorporated into kanban systems. Signs are placed around the facility to signal shortages, when to restock, safety measures and guidelines for tools and materials.

2.3.2.2 5S Plan

In addition, the 5s plan is a philosophy of operation used as an execution tool (Carreira et al, 2006). The tool is part of the lean analysis where elimination of waste and variation is the end goal. It is known as one of the simplest tools used for improvement in a facility. The 5S's follows the sequence as shown and the bracketed words are the famous Japanese words used: (Ramu, 2017)

1. **Sort** (Seiri) – Unnecessary items and materials are removed or discarded. It will reduce safety issues and provide more space.
2. **Set in order** (Seiton) – Ramu, (2017) states, "A place for everything and everything in its place". Items, tools, materials used should be placed where easily accessible and clearly marked to ease the process and avoid confusion. Otherwise, tools should be moved if not needed.
3. **Shine** (Seiso) – The facility environment needs to be clean. It includes both the facility and all that is present in the facility including the machinery. This will reduce health risks and provide environmentally friendly atmosphere and environment.
4. **Standardise** (Seiketsu) – Standards, check-lists, instructions should be developed to ensure maintenance of the warehouse. Standardisation reduces irregularities and involves all processes, materials, people, tools, operating environment and machinery.
5. **Sustain** (Shitsuke) – Most organisations struggle with the last step, as it is difficult to sustain the conditions. However, companies need to realise that time spent on the plan of the facility and its implications could improve flow, efficiency and profitability.

2.3.4 Systematic Layout Planning (SLP)

SLP was developed by Muther in 1973 and is a tool that aids in the planning of a facility layout (Mital, 2008). The tool is advantageous, as it sets out the layout of the facility in alternative ways in a way that the facility planner can better understand space requirements (Tompkins et al, 2010). The system follows a six-step procedure as follows:

1. Determination of the area for each product category or department.
2. Development of an activity relationship chart, as shown in **Figure B. 8.**
3. Draw up of a Nodal diagram. This is a graphical representation of the relationship chart, **Figure B. 9**.

4. The nodal arrangement is converted into a grid representation indicating the set required space given for each component, or process, **Figure B. 10**.
5. Templates are drawn for each area, as indicated in **Figure B. 11**.
6. Templates are arranged in the same relation as step 3. The shape of the areas is adjusted to fit the shape of the facility.

Furthermore, in step 2, the Activity Relationship Chart is much like the interrelationship diagram as explained before. It describes the degree of closeness between the various groups of products or departments. The relationship is based on the movement of products, equipment, flow and employees involved. A code/ key will be used to distinguish between the levels, typically A, E, I, O, U and X are used. The SLP system could be used for ICM by categorising the products into its various groups and finding the most appropriate placements based on the analysis.

Multiple analysis tools could be used or even a combination of all of them to find the best results possible.

2. 4 Program

A well-maintained inventory system regulates stocks and keeps control of stock levels reducing incidents from occurring. Multiple programs exist for stock control; however, the company is currently using a program called *Quickbooks. Quickbooks* is a management accounting system that has features for stock-taking. Another program could be used to gather information of stock characteristics such as Microsoft Excel which could be imported into Quickbooks at a later stage.

After all needs and requirements have been determined through various tools and techniques an appropriate program is needed to bring the design to existence. A study of the different programs is displayed in **Appendix B, Table B. 1**. The advantages and disadvantages should be taken into consideration when deciding on the program. The program selected needs to best fit the company's requirements and goals.

2.5 Conclusion of Literature Review

The Literature Review summarised and highlighted the significant concepts to be used in **Chapter 3**. From previous studies, it has been proven that the designing and planning of a warehouse is a process that is both intricate and complex. Many principles, tools and techniques are used to maximize space and provide an efficient layout. The relevant techniques should be selected based on the requirements of the company, ICM. Standards need to be followed to ensure regular requirements of the law and ethics are abided. The following chapter consists of the concept design that could be considered based on studies presented in the Literature Review.

Chapter 3
Concept design

3.1 Phases

The concept design is divided into four phases, consisting of the Planning, Design, Standard and Techniques used. The design is an outline of how the warehouse layout could potentially look like based on the concepts mentioned in the Literature Review.

3.1.1 Planning phase

The planning of the facility will consist of the multiple techniques, as mentioned in the Literature Review. First, an analysis of the environment is done, to identify the true causes of the problems that exist within the warehouse. The SWOT analysis, **Figure 3.1**, is used to identify factors that could lead to the development of the design or worsening of the problems at hand.

Figure 3.1: SWOT Analysis of the warehouse layout

When planning, these problems should be investigated using an *Interrelationship Diagram* to where causes, effects and links are identified. Multiple other tools could be used such as the *Prioritisation Matrices* to highlight key problems that need to be addressed. Ultimately, a SFP should be drawn up to establish the life cycle of the warehouse as mentioned by Tompkins et al (2010). The SFP will establish the core elements needed for the facility, resources, equipment and materials. The warehouse's requirements and standards will not stay the same, the layout will have to change in the future. Therefore, it is important to develop a plan that is flexible to be able to adapt to changing capacities.

3.1.2 Design Phase

The procedure mentioned in **Chapter 2**, **2.2.1 Factors in designing a warehouse layout,** by Airdrie (2009) will be employed. The factors in FAST are examined and incorporated into the design.

Flow is the first factor. Here, the site plan of the warehouse needs to be examined and all sections of the warehouse need to be measured. Looking at the warehouse, there are three entrances. The employer mentioned that he does not want to use the back door and will keep that locked at all times for security measures. The garage door will only be used by employees which will be both the shipping and receiving point. Customers may only enter through the reception area. The flow of products will be placed based on their characteristics in which the *Brainstorming* technique could be used. The technique as shown in **Appendix C, Figure C. 1**, will be relevant for the gathering of information of products. All these elements could be integrated into the stock list. Elements include quantities, sizes, weights and popularity. The flow of the warehouse layout will aid in the order picking process. Since the company has many large scaled products, single deep rack picking is the most optimal decision. Most products will be stacked on shelves to increase *accessibility* of products, to reduce picking time for employees.

The design should take *space* requirements into consideration. Personal belongings of the employer are also stored in the warehouse. Thus, attention needs to be given to maximize storage space for the company's products and isolating personal storage in its own section or storage unit. The *throughput* concerns over/under stock concerned with various products, thus a Pareto Analysis is essential.

The site plan was analysed for fixed fixtures and limitations and a concept design is drawn up taking all factors into consideration. The mezzanine floor was built having consulted with a professional and quotes confirmed by the employer. The concept design, as shown in **Figure 3. 2**, is an on-scale potential layout design for the ground level of the warehouse. It is based on the existing site plan but includes possible fixed shelving options. **Figure 3. 3** shows the top level and the built-in mezzanine floor that was approved. Shelving was researched and the employer decided to go with a structural system of steel frames and wooden boards for fixed shelving. Movable shelves were also purchased for further storage. These shelves will allow for changes in the future and if capacities increase, abiding *Parkinson's law.*

Aisle widths are crucial in the layout because it needs to compensate for the forklift that is used. The minimum aisle width where the forklift will be travelling is 2.74 m because it is a 1-ton forklift. In other areas where the forklift is not needed and products are small and light, the aisle width can be of a minimum of 1.52 m according to Tompkins et al (2010). Spacing will tie in with throughput as the product type determines the space needed and any special conditions required. Several machines are on a large scale, therefore, cannot be placed on shelves and will have to be placed on the ground floor. Ceiling heights and hanging lights should be examined to identify restrictions when determining shelf heights.

As discussed earlier, programs form an essential part of the planning and solution to the problem. Microsoft Excel is one of the most common user-friendly programs used for stock-taking. Essentially, the stock list will be listed in Excel which will then be imported into the company's current stock-taking program, *QuickBooks*. The program chosen to continue the design with is *Chief Architect*. There were many advantages in the decision, as the company already was in possession of the program. Therefore, the student no longer needed to purchase the package. The program is user-friendly and there are many tutorials online if help is needed. The following has been drawn-up on *Chief Architect* to be used as a concept design. It is to scale and dimensions of shelving and flooring have been taken into consideration.

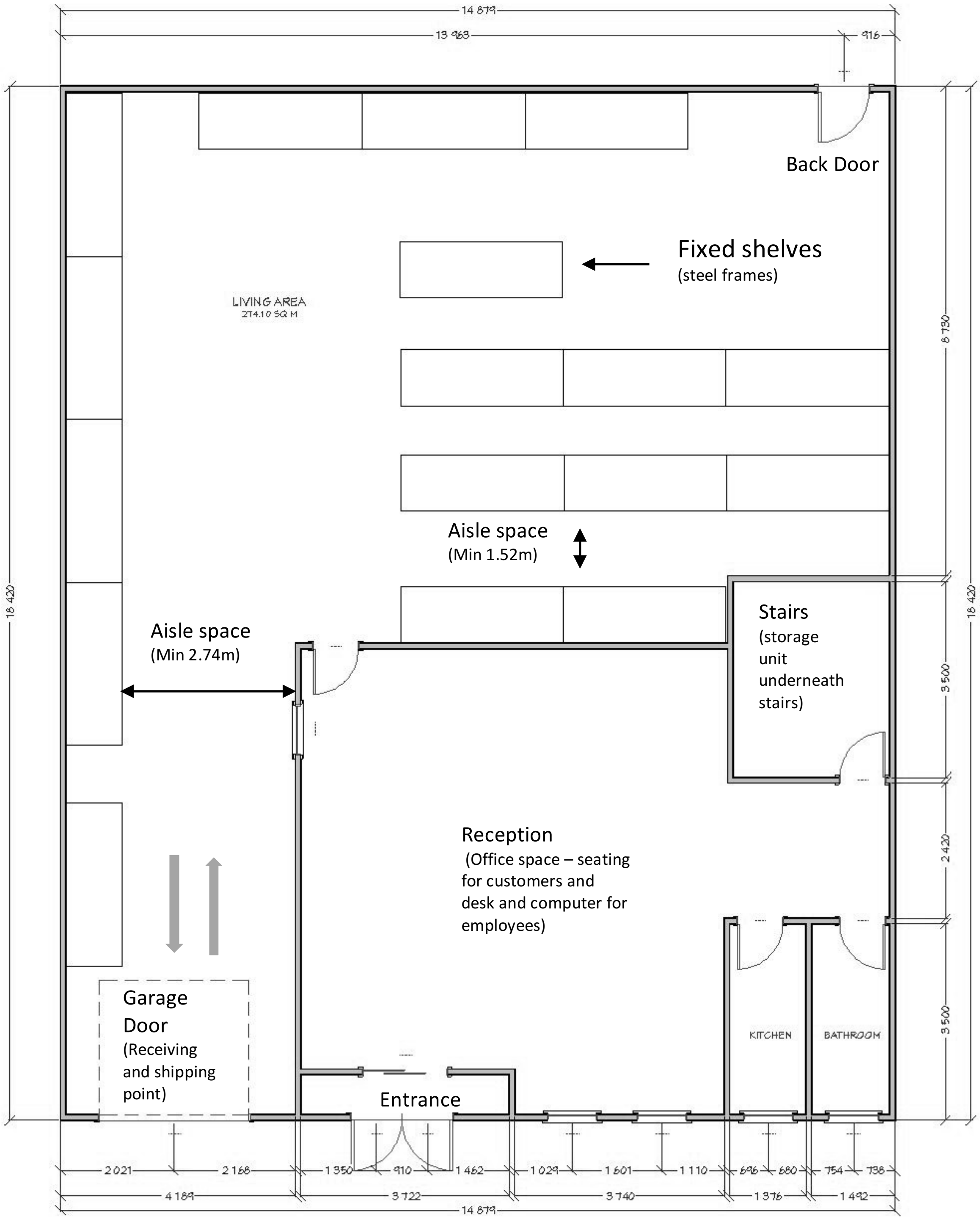


Figure 3. 2: Concept design for ground floor of warehouse

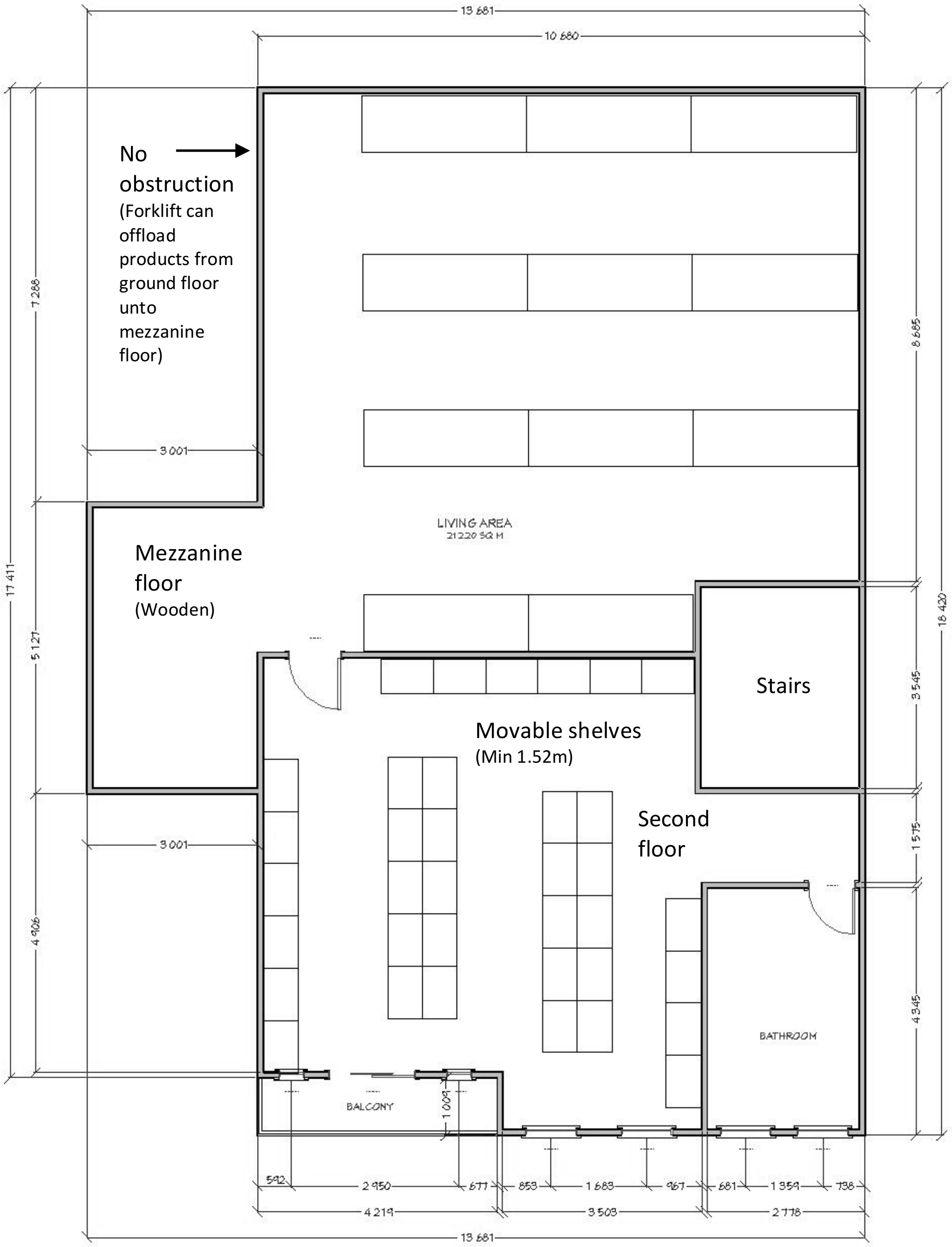


Figure 3. 3: Concept design for top level of warehouse

ICM Industries only deals with finished goods; this makes storage planning easier. The employer is keen on using the system of block stack racking and batch picking as most products are packaged in boxes which is suitable for cube utilisation. Binning and shelving will be used for smaller products on the second floor where there are movable shelves. As ICM is still a small company there will be no need for automatic retrieval systems, however if demands grow it could be something to consider. Storage will follow the racking system determined by Gulati, (2009) and Sonjoy (2013). By identifying SKU and defining the unit loads which in this case the company is in possession of several. Pallets are both 2-way and 4-way and are double faced. The storage capacity should have vertical and horizontal spacing in the design to provide for maximum utilisation of storage space.

3.1.3 Technique Phase

The ABC Analysis will most likely be used once the stock list is drawn up. The analysis will determine the needs and requirements of the various products and their placements thereof. It will be based on popularity, size, and weight. The ABC will be incorporated into the Pareto Analysis, where 20% of the products will be identified as high priority and the rest of 80% could be shelved further away from shipping and receiving points. ABC could be used coherently with Systematic layout planning. After having established the products and its characteristics, concept block designs can be drawn up and systematically placed.

Lean will be implemented to reduce and prevent wastage from occurring. The 5s plan could also be integrated into the plan of the design by looking at each S to reduce wastage and variation. Kanban systems would assist in the efficiency of the layout of the warehouse. Signs could be used to navigate employees to the right places, thereby reducing order picking time. These signs should clearly display the type of product and descriptions if different identification numbers exist.

3.1.4 Standard Phase

Overall the facility needs to be a place of efficient storage and work process. Standards should be placed to ensure it is performing to its function. Structural systems need to be firm and reliable because products are large and heavy. The environment needs to be cleaned and maintained according to the standards of the employer. Also, to ensure that it is a suitable environment for employees to work. Additional lighting should be installed to cater for the order picking process. Fans could be installed if there are special conditions otherwise windows and doors could just be opened.

The safety and security of the warehouse and employees has already increased due to the new location of the warehouse. However, additional measures must be placed to prevent any theft or future incidents. Alarm system will be installed and the windows and doors will be tinted. Quotes were sent out and the employer has agreed on the quote received, as shown in **Appendix C**, **Figure C. 2**. Safety in the terms of work environment guidelines for employees needs to be implemented. Employees should be briefed on safety equipment, tools and materials to prevent accidents from occurring. The facility needs to be equipped with safety gear and fire protection equipment.

3.2 Document Phase

All phases will be considered in the **Chapter 4**, where a variety of tools and techniques will be used collectively to find the best solution. These methods will clarify which design option that should be chosen. A detailed stock list will also be drawn up in the next chapter, for the employer to have control over the inventory system. The list will include all characteristics mentioned in the planning phase, to ensure all relevant data needed is presented.

Chapter 4

Model Development

To follow, various design concepts will be drawn up and presented. These designs will aid in choosing the final design concept, concerning the placement of shelves. The stock list will be used in conjunction with the model and the most appropriate placement of products will be identified.

4.1 Planning Phase

The SWOT Analysis completed in the Concept Design, identified external factors that would affect ICM Industries. To further study the issues the company is experiencing. An *Interrelationship Diagram*, **Figure 4. 1**, is drawn up to find the causes of these problems and how they are related to one another. The diagram also identifies the effects and outcomes of the problems. As seen in the diagram, there are a number of issues affecting ICM's business. Mainly, the problems are caused by the absence of a stock list and the lack of a design layout. These two issues should be further investigated, while also solving the minor causes. Additionally, security measures should be installed and training and guidance should be given to employees. ICM will also have to instil rules and standards to prevent these problems from reoccurring. If the company focuses on these causes, the effects will be eliminated or drastically reduced.

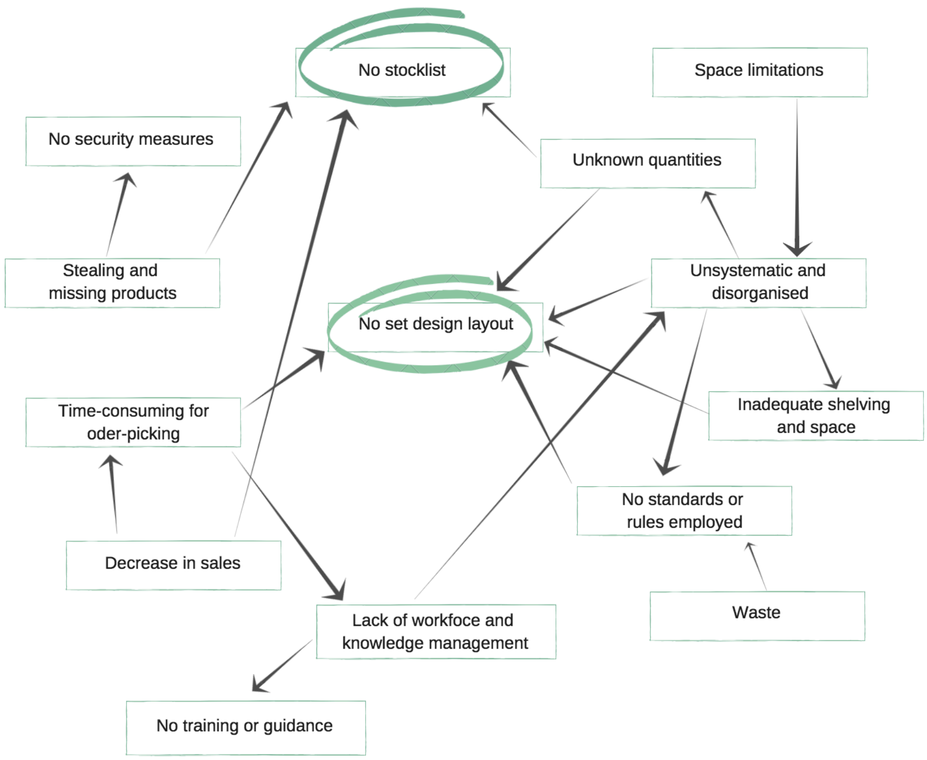


Figure 4. 1: Interrelationship Diagram for ICM

In addition, the *Prioritisation Matrix* will establish the urgency and importance of the problems experienced. This will determine what will need to be solved first and what could be done at a later stage. As depicted in **Figure 4. 2**, the issues highlighted in the *Interrelationship Diagram* are of most importance. Whereas, for example, the *Kanban* and *Lean* techniques could be done after the design of the warehouse has been set up.

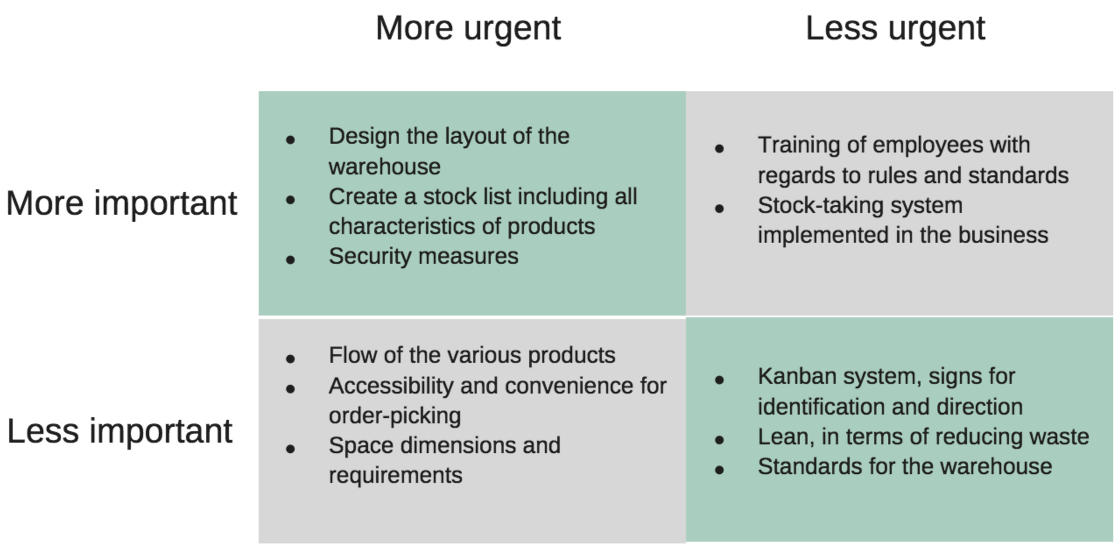


Figure 4. 2: Prioritisation Matrix

Moreover, a Strategic Facility Plan, as shown in Table 4.1, has been composed for ICM Industries, for the next four years. This is to ensure that the goals of maintaining a well-organised warehouse follows through. The plan was consulted with the all stakeholders involved and will continue to be analysed throughout the years for any improvements or changes that need to be made.

Table 4.1: Strategic Facility Plan for the next four years

Year	Facility planning
1	A full check needs to be done, in order to ensure products are still in their allocated spaces. If additional products have been added, the stocklist should be updated, spaces identified and labelled.
2	Shelving could be reorganised, removed or added to the floor. A recount of all existing products needs to be done. Employees will need a refresher-course on safety and security measures, as well as, on waste reduction.
3	The employer should ensure whether the needs of the facility are filled and check whether it is running according to the goals set. If goals have changed, further work needs to be done in achieving these goals.
4	The complete Ten-step Facilities Planning process should be conducted for the next lifecycle of the facility. This is due to, too many changes and problems that appear after years of the original design. The company might have to think of ways to expand their warehouse space if there is a growth in sales.

4.2 Design Phase

The design phase consists of the drawing up of the stock list to be used by ICM Industries. As well as, illustrating alternative design concepts to ultimately find the final design, that will best cater for all the requirements discussed with the employer.

4.2.1 Stock list

The stock list was prepared, taking all the elements and product characteristics into consideration, as listed in the Brainstorm map. The Gemba technique of 'walking the floor', was used to identify the various products and quantities. The products were also analysed on the company website and order forms. The stock had to be counted by hand to obtain an accurate representation of the quantity on hand. Employees contributed to the identification process because certain products were too heavy to lift, thus the forklift was needed. A constraint that arose was that the employees were not available all the time, hence time had to be carefully planned and utilised.

The data was compiled on *Microsoft Excel,* which would later be imported into ICM's inventory system, *Quickbooks*. The list consisted of over 600 products**,** however, the warehouse only had about 117 products present. The rest were either in the office or still has not arrived from shipment. Thus, a separate list was developed for the non-present stock, to be used for future purposes. For the purpose of this project, the 117 products, as shown in yellow in **Appendix D**, **Figure D.1**, will be studied and used. Though, the rest of the products will be listed for the company's personal use for future endeavours, if a change is required.

Accompanying the stock list, labels, as shown in **Figure 4. 3**, will be made for each of the product types and placed in the designated area. This will make use of SKU in which the label will specify the type, description, dimension and weight, to assist in the identification process and whether it will need transportation or not. This will reduce the order-picking time, by making it more convenient and accessible. Employees could easily find the desired product, making it efficient and well-organised.

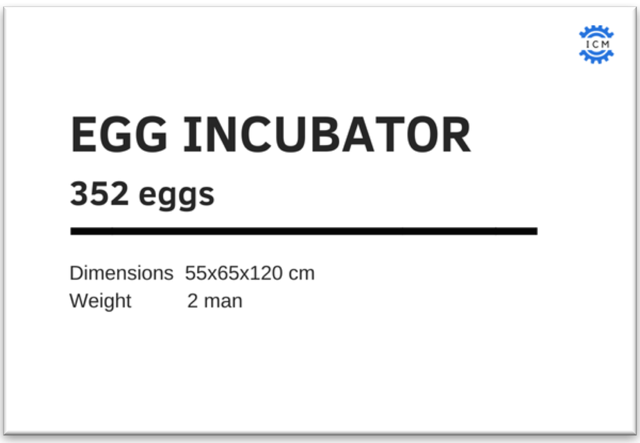


Figure 4. 3: Label for products

4.2.2 Alternative Design Concepts

In the design phase, alternative concepts and designs are drawn up with the employer, to determine various opportunities and possibilities regarding the design of the warehouse floor. Employee concerns and recommendations are also included when designing the concept layouts, to ensure a sense of contribution and recognition. An essential factor shown in the problem statement and concept design, is the space limitation in the warehouse. Products should be examined and placed in the most appropriate location regarding convenience and characteristics.

Thus, the need for appropriate shelving is critical, as not only must space be used horizontally but vertically as well. Through consultation, the shelves chosen for the warehouse are both fixed (Size: 3500mm x 800mm) and movable (610mm x 914mm). Each shelf has several dividers that may be used for placing products, as shown in **Figure 4. 4.** Hence, each design will identify where the shelves could be placed for optimal space, taking into account, the dimensions of the shelves. Products that are large and heavy should be placed on fixed shelves and small and light products should be placed on movable shelves.

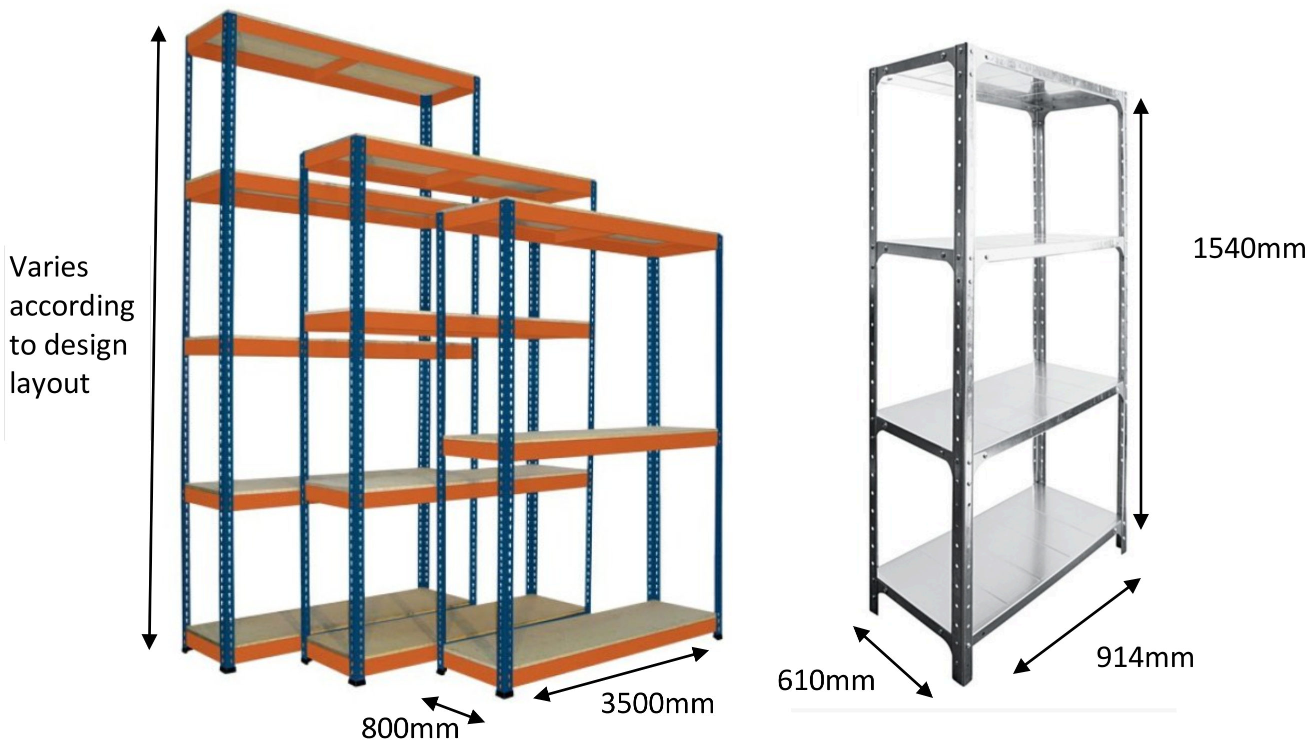


Figure 4. 4: Fixed and movable shelf dimensions

Three main designs are presented in **Appendix D, Figure D. 2 to Figure D. 7**. All fixtures, features and the height of the warehouse roof were considered. Each design will be evaluated and studied, identifying the advantages and disadvantages it carries. The observations are discussed in Table 4. 2, for each design.

Table 4. 2: The advantages and disadvantages of the three concept designs

Concept	*Advantages*	*Disadvantages*
Design 1	• Aisle space requirements are met on ground floor and top floor. • Movable shelving placed in single aisles making it easy to access products and spacious for employees.	• Less shelving on ground floor. • The back-door limits space, preventing transportation of many products, the ability to pass through. • There are unused spaces. • The window is blocked preventing circulation of air. • Products may not be offloaded from the ground floor onto the mezzanine floor using a forklift, due to shelving being present. • There are not as many shelves on top floor.
Design 2	• There is additional shelving space, compared to Design 1. • It is possible to offload products from the forklift on ground level to the top floor.	• There are many unused spaces within the warehouse. • Aisle spaces are too small on ground level, preventing forklifts from moving large products when stacked there. • There are blockages from shelves, windows and doors, creating a hassle whenever the windows and doors need to be opened. • Placement of shelves not practical or feasible.
Design 3	• Enough space is left at the back door, in case, access is needed. • Aisle requirements are met for both personnel and forklift movements. • The shelving numbers are good on both floors. • There are additional shelves on the mezzanine floor level. • Enough space is left for the forklift to offload products from the ground floor.	• There is not enough space on top floor for other uses.

4.3 Technique Phase

Numerous techniques and methods are used to find the placement of products, such as the *ABC Analysis* and *Systematic Layout Planning*. Additional methods are established for the maintenance and ongoing preservation of a well-organised warehouse, such as *Lean*, the *5S plan* and *Kanban systems*.

4.3.1 ABC Analysis

The tools and techniques used, will be applied on the present 117 products that are stored in the warehouse. This list is then used in the ABC Analysis, as shown in **Figure 4. 5**, in terms of each of its factors, to find the different category of products. The ABC categories are identified according to their *popularity,* as it has a significant impact on the placement of products. As the more *popular* a product is, the more likely the employee will need it. Consequently, the list was sorted starting from weekly, monthly, biannually, quarterly, yearly to storage. As mentioned, 20% of the list will be considered as *Category A,* 30% for *Category B* and 50% for *Category C.* Category A products should be placed at easily accessible areas and should be near the receiving and shipping point. Category B products could be placed anywhere in the middle of the warehouse. Lastly, *Category C* products may be placed far away from shipping and receiving point because it is hardly in demand.

ABC	Item Name	Description	popularity	size	weight	Quantity On Hand
A	Drain pump VS1500F	Drain pumps	Quarterly	Medium	1 man - moderately heavy	6
A	Drain pump VS550F	Drain pumps	Quarterly	Medium	1 man - moderately heavy	5
A	Drain pump VS750F	Drain pumps	Quarterly	Medium	1 man - moderately heavy	3
A	Drain Pump VW1100F	Drain pumps	Quarterly	Medium	1 man - moderately heavy	8
B	Water pump CPM 158	CPM158	Quarterly	Small	1 man -light	1
B	Water pump CPM130	CPM130	Quarterly	Small	1 man - light	4
B	Water pump CPM152	CPM152	Quarterly	Small	1 man - light	5
B	Water pump Jet 100S	Jintai pump	Quarterly	Small	1 man - light	4
B	Water pump Jet 60S	Jintai pump	Quarterly	Small	2 man - light	7
B	Water pump STCM-050	STCM-050	Quarterly	Small	1 man - light	7
B	Water pump STCM-075	STCM-075	Quarterly	Small	1 man - moderately heavy	8
B	Water pump STCM-100A	STCM-100A	Quarterly	Small	1 man - moderately heavy	12
B	Water pump STCM-150A	STCM-150A	Quarterly	Small	1 man - moderately heavy	6
B	Water pump STCM-200A	STCM-200A	Quarterly	Small	1 man - moderately heavy	2
B	Drain Pump 180W	submersible pump	Quarterly	Small	1 man - moderately heavy	9
B	Drain Pump 250W	Drain Pumps VXM12 250W 0.35HP Single Phase: 220V-240V/50Hz	Quarterly	Small	1 man - moderately heavy	5
B	Drain pump SPN-550F	Drain pumps	Quarterly	Small	1 man - moderately heavy	8
B	Alternator 144	144kw	Biannual	Large	Forklift	1
B	Alternator 22	22kw	Biannual	Large	Forklift	2
B	Alternator 30	30kw	Biannual	Large	Forklift	2
B	Alternator 32	32kw	Biannual	Large	Forklift	1
B	Alternator 40	40kw	Biannual	Large	Forklift	2
B	Alternator 68	68kw	Biannual	Large	Forklift	2
B	Alternator 96	96kw	Biannual	Large	Forklift	2
B	Alternator TFW60	TFW60	Biannual	Large	Forklift	1
B	Booster Pump PSR 253M	Booster Pump PSR 253M 750W	Biannual	Small	1 man - moderately heavy	1
B	Booster Pump PSR 255M	Booster Pump PSR 255M 1100W	Biannual	Small	1 man - moderately heavy	3
B	Booster Pump PSR 453M	Booster Pump PSR 453M 1100W	Biannual	Small	1 man - moderately heavy	1
B	Chicken broiler takes 9	Broiler for chicken	Biannual	Medium	1 man - moderately heavy	2
B	Chip fryer	Fryer for chips	Biannual	Medium	2 man	2
B	Chip fryer 2 barrel	Fryer for chips	Biannual	Medium	2 man	1
B	Circuit Breaker 1 Pole 10 A	1P 10A (240 pieces in 1 box)	Biannual	Small	1 man - light	10
B	Circuit Breaker 1 Pole 16 A	1P 16A (240 pieces in 1 box)	Biannual	Small	1 man - light	7
B	Circuit Breaker 1 Pole 20 A	1P 20A (240 pieces in 1 box)	Biannual	Small	1 man - light	4
B	Circuit Breaker 1 Pole 25 A	1P 25A (240 pieces in 1 box)	Biannual	Small	1 man - light	3
B	Circuit Breaker 1 Pole 32 A	1P 32A (240 pieces in 1 box)	Biannual	Small	1 man - light	2
B	Circuit Breaker 1 Pole 40 A	1P 40A (240 pieces in 1 box)	Biannual	Small	1 man - light	4
B	Circuit Breaker 1 Pole 50 A	1P 50A (240 pieces in 1 box)	Biannual	Small	1 man - light	1
B	Circuit Breaker 2 Pole 20 A	2P 20A (240 pieces in 1 box)	Biannual	Small	1 man - light	3
C	Circuit Breaker 2 Pole 30 A	2P 30A (240 pieces in 1 box)	Biannual	Small	1 man - light	3
C	Circuit Breaker 2 Pole 40 A	2P 40A (240 pieces in 1 box)	Biannual	Small	1 man - light	1
C	Circuit Breaker 2 pole 50 A	2P 50A (240 pieces in 1 box)	Biannual	Small	1 man - light	1
C	Circuit Breaker 2 Pole 63 A	2P 63A (240 pieces in 1 box)	Biannual	Small	1 man - light	1

Figure 4. 5: ABC Analysis

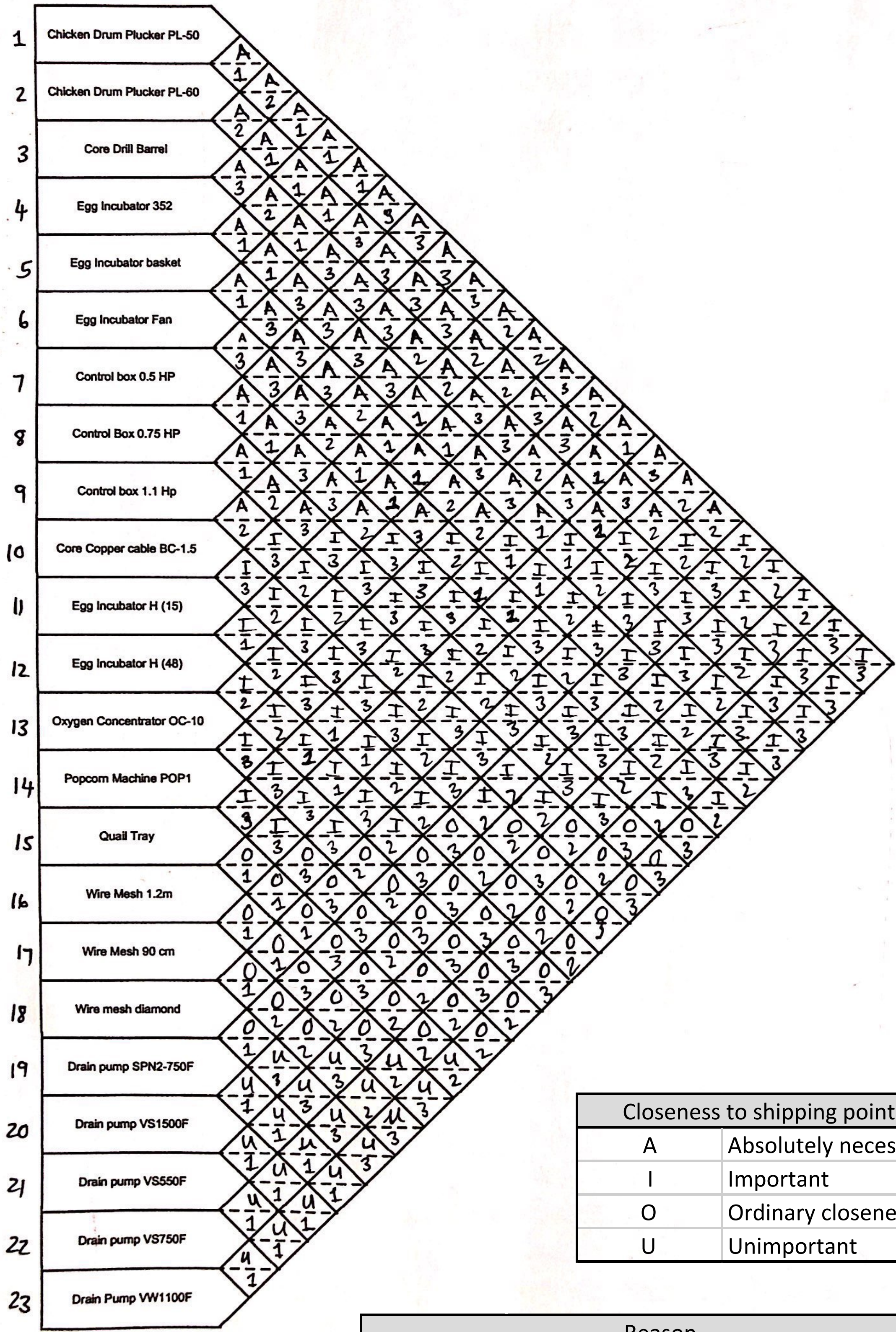
4.3.2 Pareto analysis

The Pareto analysis, shown in **Appendix D, Figure D. 8**, develops from the ABC Analysis. As mentioned, all products listed on the independent variable are organised according to their *popularity*. The blue graph represents the ranking of *popularity*, which consists of the numbers 1-6, in which the hierarchy starts from weekly to storage, as shown in the key. The red graph indicates the percentage at which products are crucial to the warehouse. The graph shows 20% of products that are valuable to be near the shipping point and the 80% that could be placed further away. The 20% of products aid in the decision-making used for the selection of the design that will, in turn, create a significant overall effect. It could also be used to determine stock quantities by examining products *popularity*. In this way the employer could forecast stock quantities for the future.

4.3.3 Systematic Layout Planning

In addition, *Systematic Layout Planning* is used to identify the various spaces that the products could be placed. The SLP will only be prepared for products in Category A, since the placement of these products is most critical, as it should be placed near the receiving and shipping points. There is not much importance of where Category B and Category C products should be placed in the warehouse because it is not as popular as Category A products.

First, a Product Relationship Chart, **Figure 4. 6**, will be drawn up to determine the closeness rating and the reasons behind the closeness as represented in the keys. Then, a Relationship Diagram, **Figure 4. 7**, is drawn up, using the listed products. Each product is numbered and the correlations are shown with various lines. The more intensified the line the more similarity exists between the products, which represents the closeness needed. After, which a Space Relationship Diagram, **Figure 4. 8**, is established. The space dimensions are shown in terms of small, medium and large. Finally, Alternative block layouts, are illustrated in **Figure 4. 9**, where different concepts are planned for the arrangement of products which will contribute to the final design in terms of relationship and how it will fit into the set layout. Concept C will be used in the final design, as it best fits the layout. There will be a few alterations made when considering the product characteristics and shelving placements.



Closeness to shipping point	
A	Absolutely necessary
I	Important
O	Ordinary closeness
U	Unimportant

Reason	
1	Similar products
2	Convenience according to characteristics
3	Logical thinking

Figure 4. 6: Product Relationship Chart for Category A

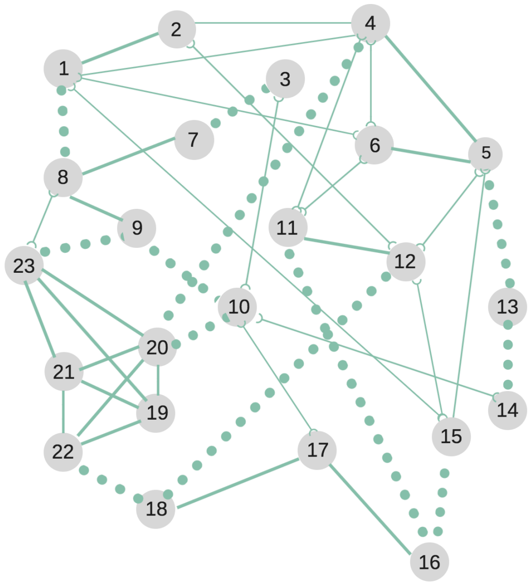


Figure 4. 7: Relationship Diagram

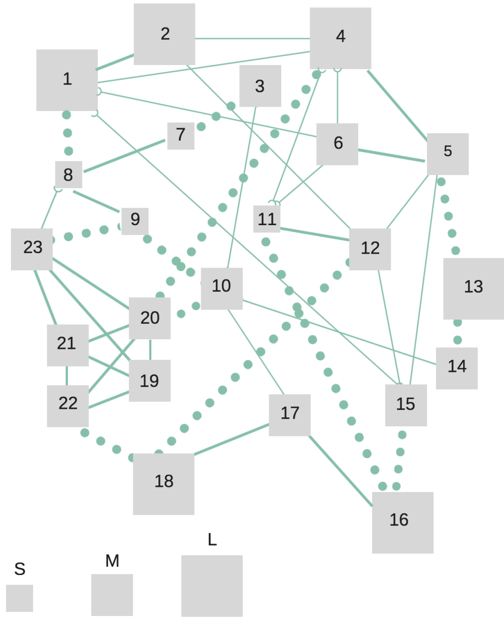


Figure 4. 8: Space Relationship Diagram

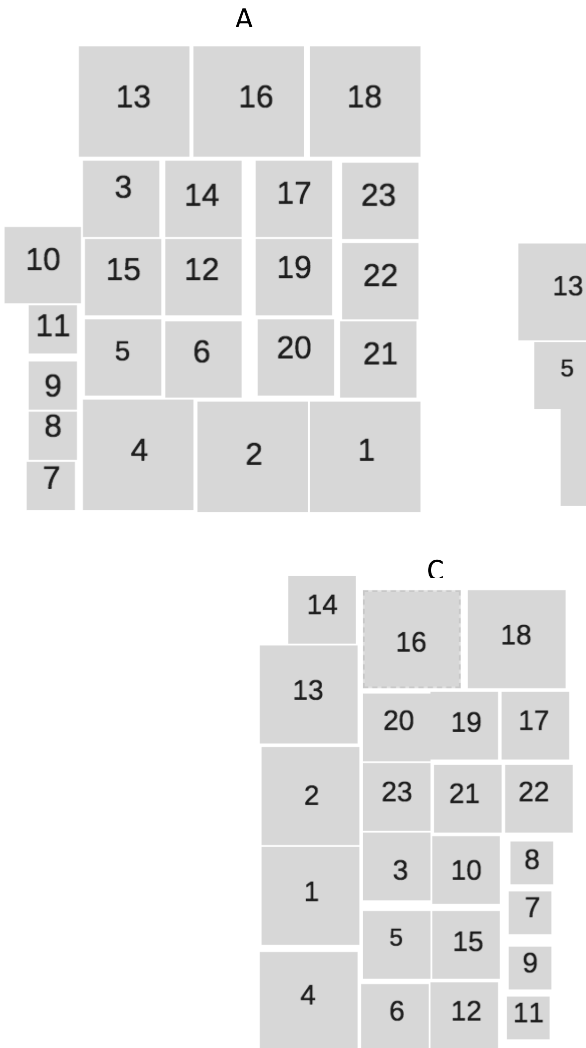


Figure 4. 9: Alternative block layouts

4.3.4 Lean

Lean is applied within the facility to reduce waste, and lead times while improving order-picking times, as mentioned by Baby, B. et al, (2018). Once the wastages are identified, as illustrated in **Figure 4. 10**, the activities which do not add value will be eliminated or greatly reduced.

To follow are the lean wastages that affect ICM Industries. Overproduction consists of ordering the right quantities of products in relation to demand. ICM needs to view their sales and forecast the correct amounts to reduce the stock numbers if not needed. This will create more space and prevent overstock. Motion will be reduced, once products are in their allocated spaces. Employees will travel less and machines will not have to be moved so often. Customers will no longer have to wait too long for a product from the warehouse, as the process will be quicker and more convenient. The same goes for transportation, as the forklift will not have to be used so often, which reduces petrol and operating costs. Rework needs to be done on products which have a fault or if parts are missing. It is essential to ensure all products are in perfect condition. If certain products are rarely being sold, the employer will have to take note of this to prevent from ordering more in the future. The remaining products should also be sold at a discount price because if the products are just kept in storage, it will lose its value as time passes.

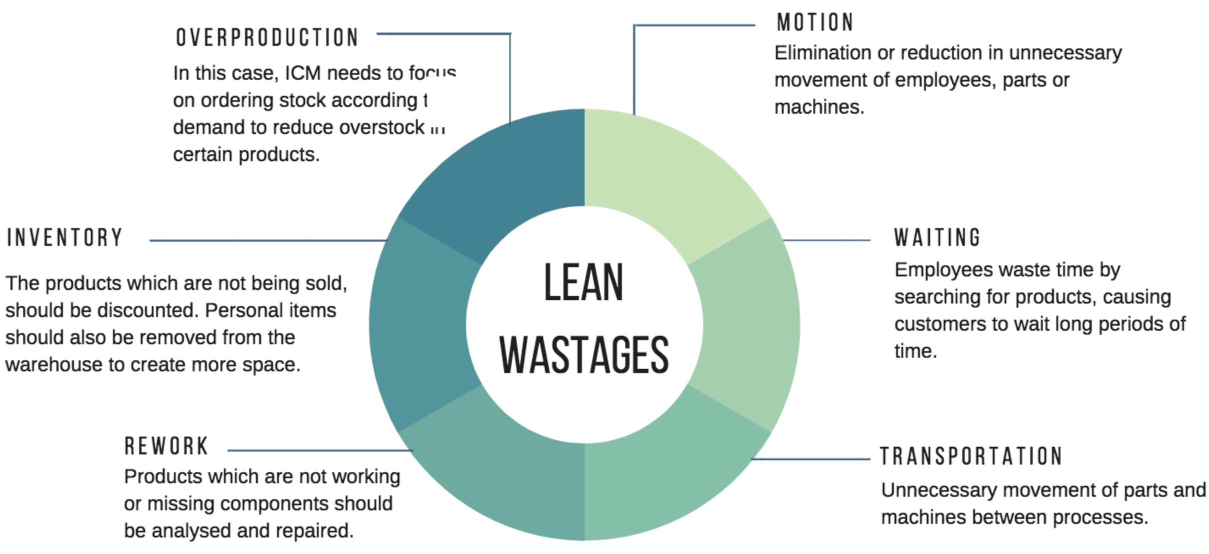


Figure 4. 10: Lean Analysis

4.3.5 5S plan

The 5S plan roots from the Lean analysis and is used as an execution tool to improve the running of the warehouse. The 5S order is shown in **Figure 4. 11**, and if followed, could lead to a higher level of efficiency. First, the products are *sorted* into their labelled areas and all unnecessary items and material should either be thrown away or recycled. Once products are *set in order*, the order-picking process will become efficient and quicker. The warehouse should *shine*, in terms of cleanliness and sanitation, this could be accomplished by hiring a regular cleaner to come by once a week. This will instil confidence within the employees that the warehouse is a healthy and safe working environment. Employees should also be aware of principles such as the *3R*'s and Lean to reduce waste. The employer needs to establish rules and *standards* within the warehouse the maintain order. Checklists, guidelines and safety concerns should be presented and followed. Lastly, to *sustain* this working environment, all four mentioned S's have to be in place to ensure the warehouse is running as efficient and smoothly as possible.

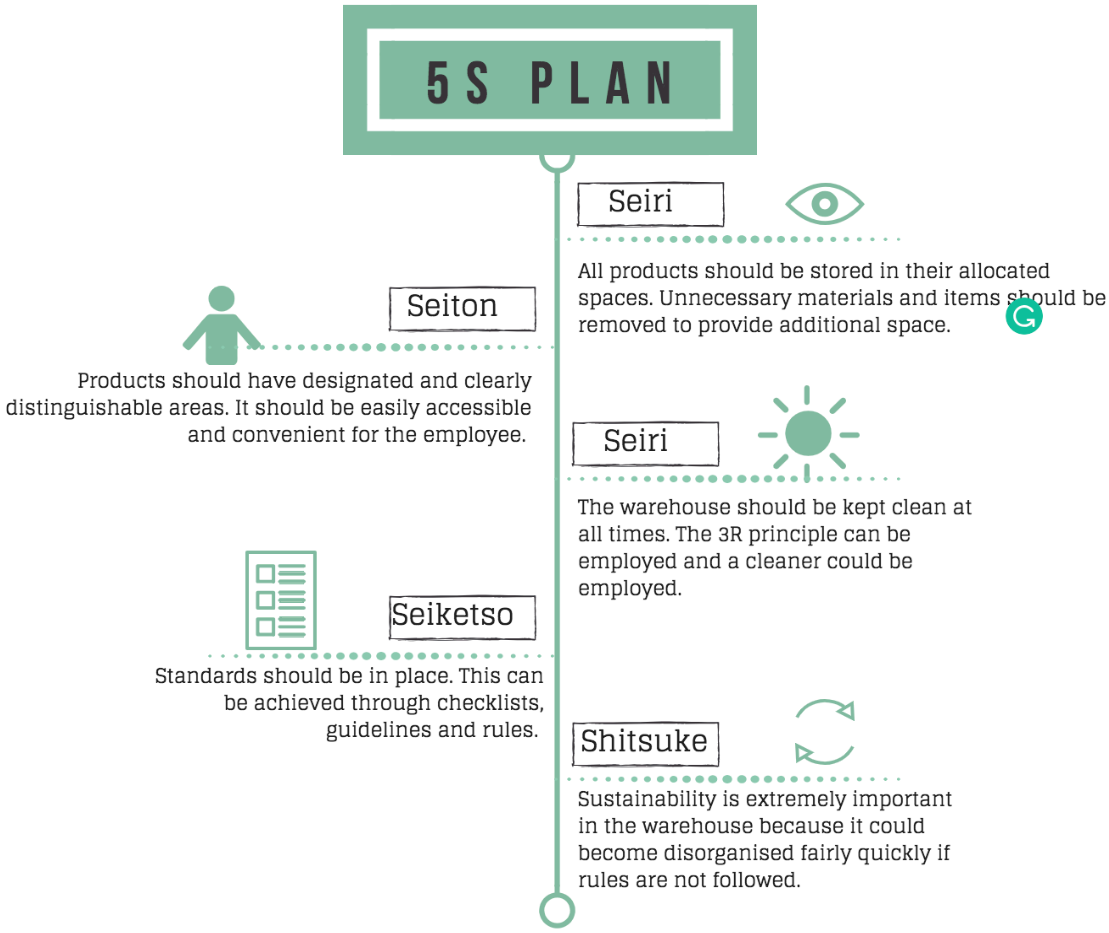


Figure 4. 11: 5S Plan

4.3.6 Kanban

ICM Industries makes use of the Kanban technique throughout the warehouse. The labels for the products were created to ease the order-picking process. Tools will have their allocated spots to ensure order and structure. Checklists and guidelines are illustrated in poster forms, as shown in **Appendix D**, **Figure D. 9**.The posters were created for employees to run through, every time they leave the warehouse. These will aid in reducing waste, decreasing costs and ultimately improving the flow of the warehouse. Safety conditions are also shown through various signs and posters.

4.4 Standard Phase

This phase deals with all the standards that should be put in place to maintain the efficiency and running of the warehouse. The standards consist of structures, environmental aspects, safety and security, aisle requirements, lighting and thermal conditions. If standards are followed through, ICM will be able to maintain and sustain a good working environment for employees and in turn, aid the employer in business processes.

4.4.1 Structural systems

Shelving is chosen according to the product categories available. Not all shelves have been used in the design, therefore all additional shelves will be kept in storage for future changes. The structure of the mezzanine floor is of great importance and has been built with heavy-duty wood, to allow for heavy products to be placed on. It is held up with steel columns that are durable and strong.

4.4.2 Environmental

The warehouse environment should be clean and provide for good working conditions. This is achieved by establishing the *3R Principle* of Reduce, Reuse and Recycle. By creating awareness amongst employees, waste will be reduced, making it easier to maintain a suitable working environment. A cleaner could be employed, once a week, to make sure all health and safety concerns are eliminated. This will be a small percentage of the cost to be made at the benefit of health risks or accidents. Posters in relation to the *Kanban* system can make the employees aware of this initiative, as shown in **Figure D.10**. Recycling bins are made available and employees take care to use energy resourcefully and water sparingly, to cut operation costs and most importantly to contribute to the environment.

4.4.3 Lighting

The warehouse already has ceiling lights, however, when the mezzanine floor was built it made the ground floor much darker. This made it difficult to see the products. Thus, additional lights had to be installed in those areas to aid in the order-picking process, that are environmentally friendly. It is seen as cost-effective investment for warehouse operations, as it saves up to 80%, when compared to traditional lighting technologies (Pontius, 2017).

4.4.4 Thermal conditions

The warehouse is kept locked until a certain product is demanded. In general, the air conditions within the warehouse are normal and there are no harmful substances present. Machines are in no need of certain temperatures, making it unnecessary for air conditioners or fans to be installed. It is sufficient enough to open up the doors and windows for air circulation.

4.4.5 Safety and Security

As mentioned, windows and doors were tinted and alarm systems were installed. These security measures will ensure there are no thefts or missing products. Additional locks may also be purchased. In terms of the safety of employees, safety equipment and gear has been provided to them. Posters and guidelines, such as in **Figure D. 11**, will be provided to ensure the smooth running of processes.

4.4.6 Aisle requirements

As researched the following requirements, **Table 4. 3**, will be used in the final design of the warehouse, in regards to aisle space. All fixtures and shelves are considered in terms of these requirements.

Table 4. 3: Specified aisle requirements

Aisle requirement	
1-ton Forklift	2.743 m
Personnel	0.914 m
Load	5-10% of net area
Less than 0.557 m^2	10-20 %
Between 0.557 m^2 and 1.115 m^2	20-30 %
Between 1.115 m^2 and 1.672 m^2	30-40 %
Greater than 1.672 m^2	5-10 %

4.5 Final Design

Through careful analysis, Design 3, **Figure D. 6, D.7,** will be chosen and expanded on in the final design. As it meets the requirements of the employer and best fits the aim of the project. Mainly, because it advantages out ways its disadvantages, as shown in **Table 4. 2**. All phases have been employed and a design was constructed. The final design, in **Figure 4. 12** and **Figure 4. 13,** shows where the products should be placed for effective utilisation of space and employee convenience in terms of product characteristics.

There will only be one shipping and receiving point, as the back door will be locked for safety reasons. The reception door will be used by customers only. As for transportation, ICM only has one forklift in the warehouse that will be used in conjunction with pallets for heavy-duty products. The grey arrows in the design depict the forklift movement. All shelving on the ground floor consists of fixed shelves which are placed at standard aisle requirements. This will allow for the forklift to travel in between and for employees to easily remove or add a product. All fixed shelves have three shelf compartments unless specified. *Cube utilisation* and vertical spacing have been used to maximise utilisation of available space. The mezzanine floor also has fixed shelves to prevent from shelves and products from moving and causing accidents or incidents. However, there will be movable shelves on the second floor to allow for flexibility and adaptability.

The reception area will be kept for office affairs only, as requested by the employer. Here all product transitions will be recorded and filed. The area will provide a waiting area for customers to sit and enjoy a cup of coffee, to ease the waiting time. Products that are ordered and ready for collection could also be shelved in the reception area, if small enough. There is a room area underneath the stairs that will be used for products that are personal or rarely sold. In the illustration, **Figure 4. 12** , shelves are numbered according to the number of dividers that exist on the indicated shelf. Each product type is then mentioned for the specified shelf based on all the techniques, methodologies researched and completed.

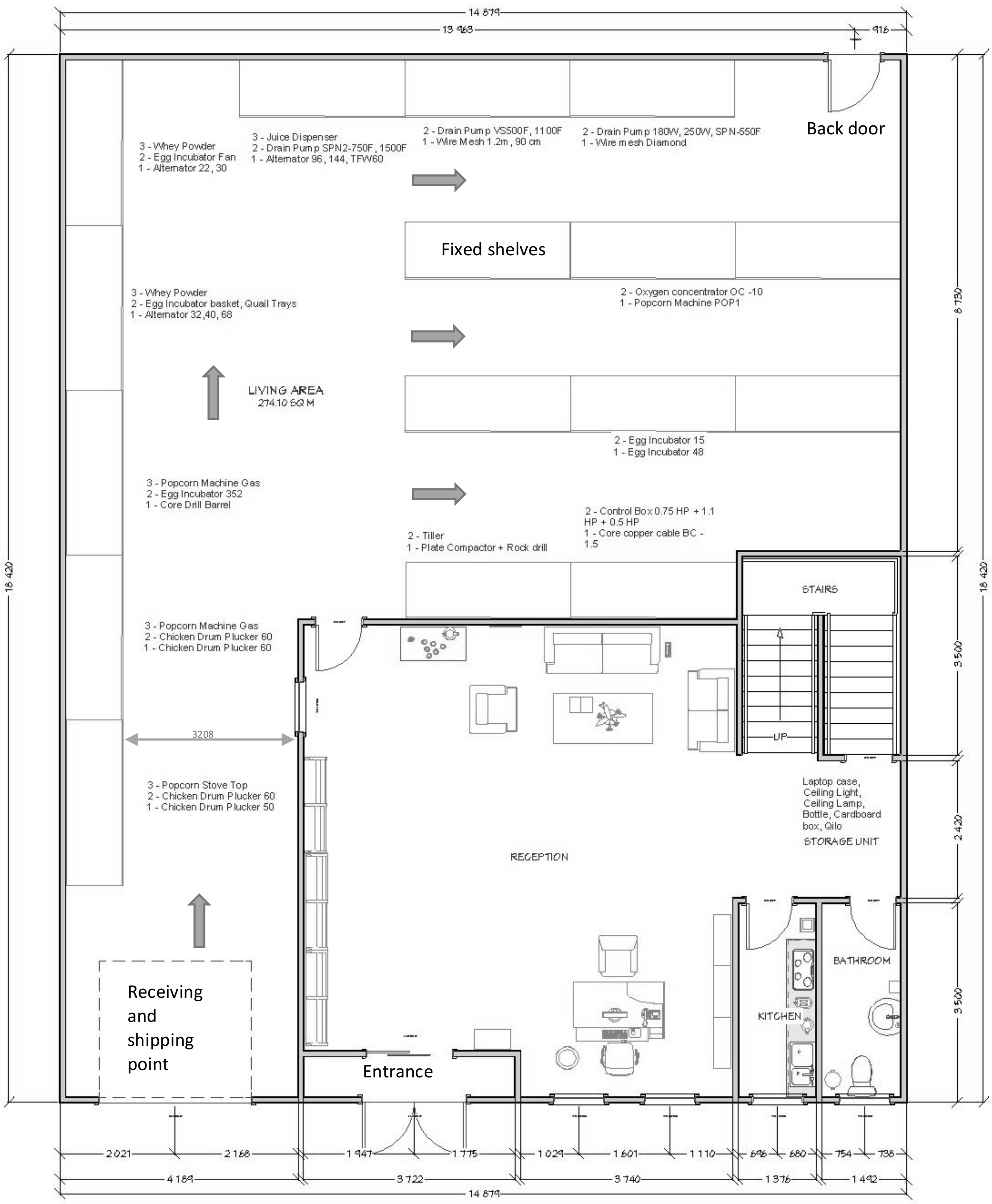


Figure 4. 12: Final design for the ground floor of the warehouse

Figure 4. 13, illustrates the second-floor product placements. Most C-Category products are placed here. Additional shelving space has been left for future stock or changes. The products are arranged in terms of popularity, weight, quantity, size and type. Each shelf has additional space for each of the product types to cater for stock increases or fluctuating stock.

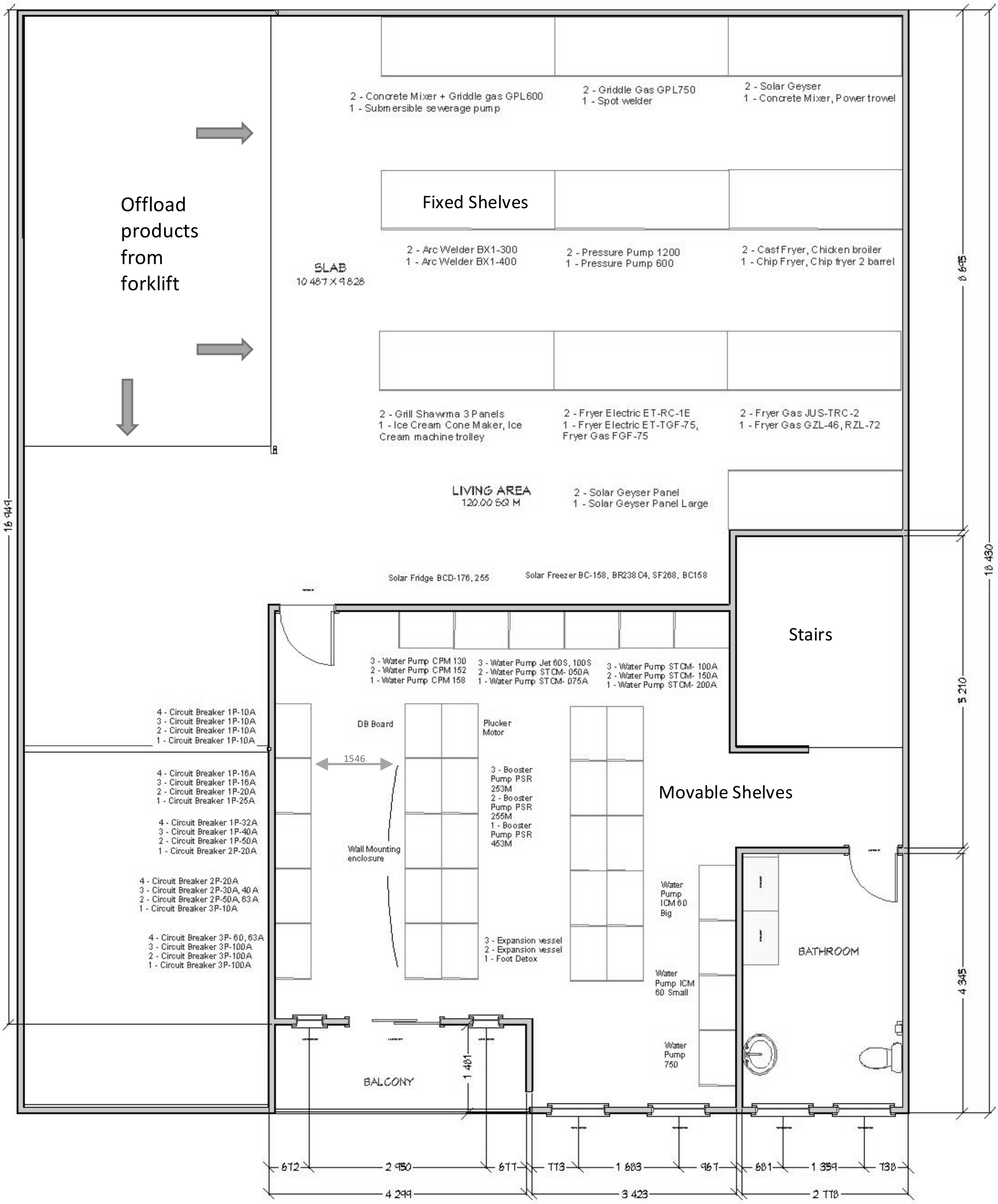


Figure 4. 13: Final design of the second floor

These could be used as a "Map" for employees to identify product placement areas. The model was generated in *Chief Architect*, **Figure D. 12**, in which a 3D model was created for the purpose of envisioning the goal of the facility plan. The employer and employees could visualise the layout plan and it allowed for a greater sense of understanding of what is expected.

Chapter 5
Validation

The final design was implemented, with the acceptance of the employer in all aspects. Ultimately, the warehouse fulfilled the functions of its intended purpose; space was utilised, order-picking time decreased, safety measures increased and stock control processes were made efficient.

Validation determines the feasibility of the model. Validation testing mainly follows through four main activities: Unit Testing, Integration Testing, System Testing and User Acceptance Testing (Anon, 2018).

5.1 Unit testing

Unit testing should validate the program used for stock-taking. The stock list on *Quickbooks* should be examined whether true and accurate results are displayed in the program. The employer will use this list for invoices and receipts as well as stock-keeping records. Initially, the employer had limited knowledge of the application, *Quickbooks*. Furthermore, the secretary was adding each product manually to invoices and receipts.

Quickbooks was thoroughly studied through internet sources and videos. Separate accounts were made with different admin privileges so that the employer will maintain access to all information and the employees (secretary and sales manager) will have access to the limited access account. The stock list was imported from Microsoft Excel into *Quickbooks* and the secretary was trained in its application, this includes the generation of invoices and receipts. Since the stock list is up to date, product types and quantities are known. The secretary is now able to notify customers if there is stock available as well as handle any other product-related concerns. The employer alone has control over stock numbers and will be able to forecast the number and type of products needed in the future. The employer will be able to track sales and quantities, as all information will be stored in the database, this is evident in **Figure 5. 1**. The employer will be aware of exact quantities, thus decreasing the chances of thefts from occurring or uncertainty.

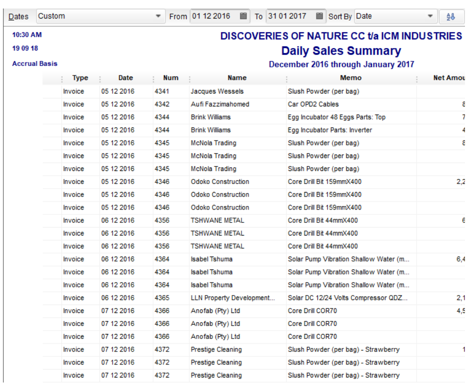


Figure 5. 1: Quickbooks application

5.2 Integration testing

Integration testing should validate the final design layout and product placement. The map of product placement is available for employees to view, making the order-picking process simpler and well-organized. Originally, some products were indistinguishable from the outside packaging, now there are labels for identification purposes. The employer and employees found the layout convenient and easily accessible. Space was used effectively and equipment had specific placements. Time tests were done to measure the duration, in minutes, it takes for the employee to retrieve a product as opposed to the previous process in the old warehouse. A test, as shown in **Table 5.1**, was done on 20 random products from the warehouse, from different categories (ABC), to see the effect the final layout had on retrieving a product.

Table 5. 1: Time taken, in minutes, to retrieve products from the old and the new warehouse

	Category (ABC)	Product type	Old warehouse (min)	New warehouse (min)
1	A	Egg incubator 352	34.27	5.32
2	A	Drain pump VS550F	43.11	7.11
3	A	Oxygen Concentrator OC-10	22.41	6.54
4	A	Chicken Drum Plucker PL-60	70.65	3.42
5	A	Popcorn Machine POP1	26.58	4.55
6	B	Booster Pump PSR 255M	11.42	6.41
7	B	Circuit Breaker 1 Pole 16 A	33.51	7.38
8	B	Water pump CPM152	45.12	8.14
9	B	Chip fryer 2 barrel	38.43	9.29
10	B	Drain pump SPN-550F	25.21	12.32
11	B	Alternator TFW60	61.44	7.33
12	C	Tiller (Electric)	21.33	8.1
13	C	Pressure Pump 600	17.25	9.24
14	C	Arc welder BX1-400	31.56	8.43
15	C	Solar fridge BCD-176	27.42	10.32
16	C	Fryer Gas GZL-46	29.48	11.35
17	C	Fryer Electric ET- RC-1E	34.59	13.52
18	C	Grill Shawarma 3 Panels	65.13	10.23
19	C	Submersible sewerage pump	19.52	14.44
20	C	Ice cream machine trolley	8.34	16.46
		Average	**33.34**	**8.995**

The graph, as depicted in **Figure 5.2**, shows the relationship of time differences for retrieving products in the new and old warehouse. It is evident that the new warehouse decreases the order-picking time significantly as compared to the old warehouse. The red lines indicate the averages, the old warehouse took about 33.34 minutes on average for an order to be found, whereas, in the new warehouse the time is 8.995 minutes. This shows how the placement of products, the product map, signs and labels assisted the employees in finding the product in a more efficient and effective manner.

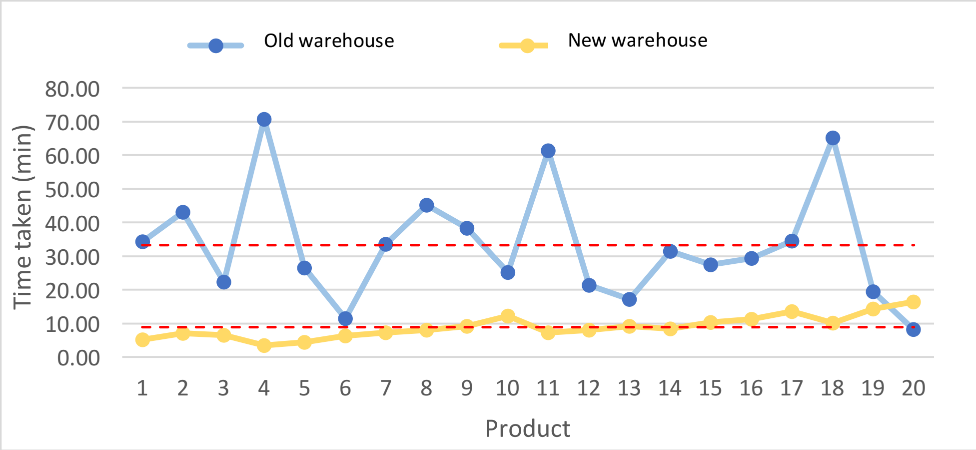


Figure 5. 2: Graph showing the time taken in minutes, to retrieve a product for the new and old warehouse

5.3 System testing

System testing validates the system that will be in place and the measures that will maintain the operation of the warehouse. This could be achieved by testing whether employees know the guidelines, rules and standards employed in the warehouse.

The employer or manager would have to perform regular check-runs, every month or two, within the warehouse to ensure the warehouse's operability is up to standard. This includes inspection of cleaning and recycling processes, as well as employee operations. Employees attended a briefing on the rules, principles and safety precautions that they must adhere to as shown in **Figure 5. 3**. This instils confidence amongst them, as they know what is required of them and they are ensured a healthy and safe working environment, mitigating the risks of accidents or unfortunate incidents. These briefings will occur twice a year, to maintain the standards in place. It is also essential for the signs, labels and posters to be up to date and clearly presented if any changes are made.

Figure 5. 3: Briefing on rules, safety and regulations

5.4 User Acceptance testing

User Acceptance testing validates the design against the requirements set out in the project. A budget was created to ascertain if costs have in fact produced benefits for ICM Industries.

The budget analysed the actual costs against the predicted amount. Testing could also be focused on how convenient and practical the design is from the employees view, who are the users of the system.

5.4.1 Budget

All these changes and designs were performed under the budget the employer had set for the warehouse facility. The budget included all shelving costs, cleaning and maintenance, security systems, environmental plans and Kanban systems that were implemented in the final design. The employer had budgeted R162 000 to be spent for the entire project. However, as shown in **Table 4. 4** the actual amount spent, totalled R127 505.72 for implementation. Thus, ICM managed to save R34 494.28, in which they could invest in the business or use to purchase more stock.

Table 4. 4: Actual and predicted budget

Budget				
			Actual	**Budgeted**
Mezzanine floor			R 49 248	R 65 000
	3680mmx10.250mm, 3800mm High ±36,000mm. Floor to carry weight loading 350 kg. Floor Media 21mm Ply Boards. 10360mm Handrail	R 43 200		
	Installation and delivery	R1 500		
	VAT @14%	R6 048		
Fixed Shelves			R 35 573.22	R 47 000
	Frames 3500mmx800mm	R7 650		
	Beams 2700mmx1600kg	R21 450		
	Row connectors 300mm	R180		
	Anchor Bolts	R425		
	Installation and delivery	R1 500		
	VAT @14%	R4 368.70		
Movable Shelves			R 24 880.50	R 30 000
	Shelves 610mmx914mm	R 10 545		
	Uprights 1905 mm	R 5 180		
	C/Plates	R2 220		
	Nuts and bolts	R2 380		
	Installation and delivery	R1 500		
	VAT @14%	R3 055.50		
Kanban system			R2 094	R 2 000
	Posters	R860		
	Labels	R1 234		
Security measures			R7 620	R 9 000
	Alarm system	R4 320		
	Locks and hinges	R1 200		
	Tinting	R2 100		
Safety measures			R4 240	R 3 000
	Safety gear	R2 380		
	Safety equipment	R1 860		
Cleaning and maintenance			R3 850	R 6 000
	Cleaner	R 1 000 (per month)		
	Lighting	R1 870		
	3R material and equipment	R980		
		Total	**R 127 505.72**	**162 000**

5.4.2 Practicality

The final design is a good indication of how space was used resourcefully particularly since the new warehouse is smaller than the old warehouse. Shelves and products have been strategically placed to ensure maximum utilisation of equipment, space and labour, as shown in **Figure 5. 4**. The mezzanine floor allowed for a significant amount additional space, as many products could be placed there. Product characteristics are crucial, as the heavy products are placed on the floor and lighter objects on shelves. Additional space was left on all shelves, if the quantities of those products increase.

Figure 5. 4: Implementation of final design

A survey was drawn up on *Google Forms*, to see how the employees viewed the implemented layout and what could be improved on in the future. As shown in **Appendix E, Figure E. 1**, employees found the new layout practical and convenient when compared to the old warehouse. Everything and every product has a certain space allocated. Moreover, employees are able to distinguish the various types of products through the use of posters and labels, making it easier to remember where each product is, as shown in **Figure E. 2**. **Figure E. 3**, illustrates how the employees strongly agreed that the order-picking process time has decreased significantly compared to before and **Figure E. 4** shows that the majority of employees agree strongly that enough space has been indicated for each of the product types and its quantities.

Furthermore, in **Figure E. 5**, employees agreed the aisles are spacious allowing for movement between shelving which also allows the forklift to get around easily, however it could be improved and set at wider dimensions in the future. **Figure E. 6**, indicates that employees do believe the implemented system for stock-taking has improved operations, though could continue to be developed to add more value.

Chapter 6

Further development

The model should consistently be examined for any developments, improvements or recommendations that would improve the performance of the warehouse. Also, whether changes are needed in the future.

To maintain a stock list that is accurate and precise, regular checks need to be done. If possible, the employer and manager should attend a *Quickbooks* course in which they could learn how to use the program to its full potential. In addition, a person could be employed for stock control, if the current employees do not have enough time. This will take the form of doing regular checks, once a month, to ensure an efficient system is in place. In addition, W websites could list quantities of product, to decrease time spent on answering phone calls.

In terms of creating additional space, personal products could be kept elsewhere and not in the warehouse. The employer should also carefully work out how much stock is needed to prevent overstock and create additional space. If the company continues to grow, another warehouse should be bought or rented, preferably in the same security complex. Considering growth, automatic retrieval systems could also be implemented to ease the order-picking process. If expanding, ICM Industries could also focus on environmentally friendly products and equipment to create a positive image for the company. This could include solar panels to be installed on the roof, as a way of saving energy. Furthermore, if crime or theft increases over time and the said security measures are not enough, the employer could implement a fingerprint system for the warehouse entrance.

Chapter 7

Conclusion

The report has defined the problem extensively, clearly outlining all areas that should be focused on and the approaches that should be used. The warehouse inventory was disorderly and there was no indication of quantities or placements. Thus, space was limited due to an unsystematic procedure of placing products, which led to increased order-picking time. Further problems arose such as customer annoyance, loss of sales, theft and increased incidents.

The project aimed to design a layout that effectively utilises space and aids the order-picking process. Research was conducted to gain knowledge and understanding of facility plans and type of layouts used in an industrial field. All of the information and data was gathered from internet sources, books, personal interviews and site visits.

Furthermore, the Literature Review assisted and guided the concept of the design layouts which are based on previous successful facility layout plans. Alternative designs have been drawn up and compared to find the best design to be used by ICM. The critical component is for the employer to be satisfied with the layout that will allow for the highest potential of space utilisation. The design is used in conjunction with the stock list, that was drawn up according to all the characteristics listed in the report. The stock list now exists on ICM's stock taking system, *Quickbooks*, where all products and quantities are present.

The final design was selected taking all factors into consideration from employer requirements to researched successful warehouse layouts. The 3D model was developed for the purpose of envisioning the final layout, allowing the employer and employees to have a sense of what the warehouse will look like. This creates a sense of involvement and motivates employees to maintain an orderly space.

The design was implemented and validation of this model was expanded, in which various tests, including unit system, integration and user acceptance tests, to validate whether the final design is feasible or not. Enough space was made in the design for all products and for additional products, and the equipment was strategically placed for convenience. The budget ensured the project was done at a reasonable cost and the time test revealed a decrease in the order-picking process. A security system is now in place and the company follows the 3R's procedure. Ultimately, the aim of the project was achieved in the sense of effective utilisation of space, equipment, labour with reasonable cost and security in place, while maintaining a safe and environmentally friendly environment. Overall, a systematic and optimal design has been implemented for the better of the company.

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Appendices

Appendix A: Industry Sponsorship Form

Department of Industrial & Systems Engineering
University of Pretoria

Final Year Project Mentorship Form
2018

Introduction

An industry mentor is the key contact person within a company for a final year project student. The mentor should be the person that could provide the best guidance on the project to the student and is most likely to gain from the success of the project.

The project mentor has the following important responsibilities:

1. To select a suitable student/candidate to conduct the project.
2. To confirm his/her role as project mentor, duly authorised by the company by signing this **Project Mentor Form**. Multiple mentors can be appointed, but is not advised.
3. To ensure that the **Project Definition** adequately describes the project.
4. To review and approve the **Project Proposal**, ensuring that it clearly defines the problem to be investigated by the student and that the project aim, scope, deliverables and approach is acceptable.
5. To review and approve all subsequent project reports, particularly the **Final Project Report** at the end of the second semester, thereby ensuring that information is accurate and the solution addresses the problems and/or design requirements of the defined project.
6. Ensure that sensitive confidential information or intellectual property of the company is not disclosed in the document and/or that the necessary arrangements are made with the Department regarding the handling of the reports.

Project Mentor Details

Company:	ICM Industries
Project Description:	Warehouse Facility layout
Student Name:	Nika Ashoori
Student number:	15009484
Student Signature:	Ashoori
Mentor Name:	Dana
Designation:	
E-mail:	dana@lantic.net
Tel No:	
Cell No:	0823428233
Fax No:	
Mentor Signature:	DanaAsh

Appendix B: Literature Review

Facility Planning Process

Figure B. 1: Template for SWOT Analysis (Anon, n.d.)

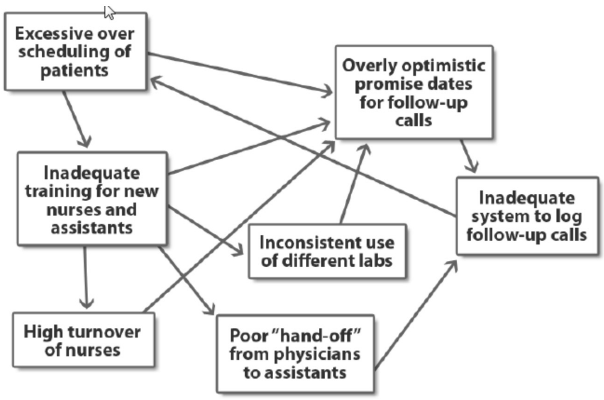


Figure B. 2: An interrelationship diagram depicting causes and effects (Anon, 2012)

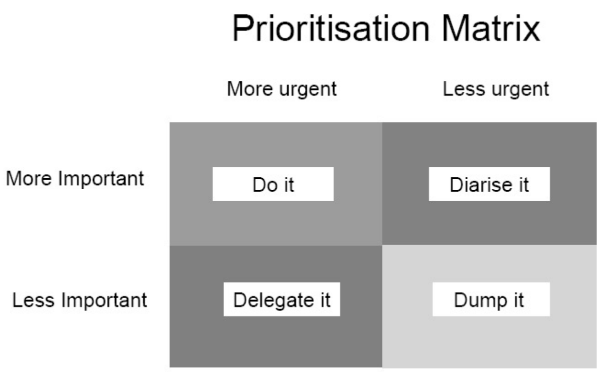


Figure B. 3: Prioritisation matrix (Anon, 2018)

Warehouse design

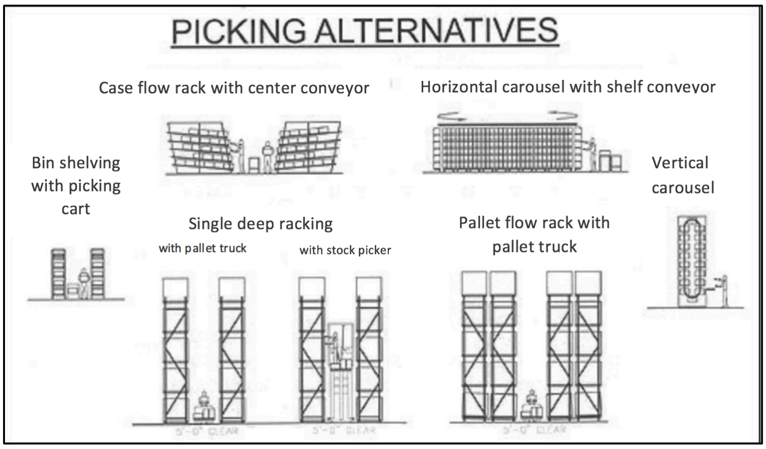


Figure B. 4: Picking alternatives (Acker, 2017)

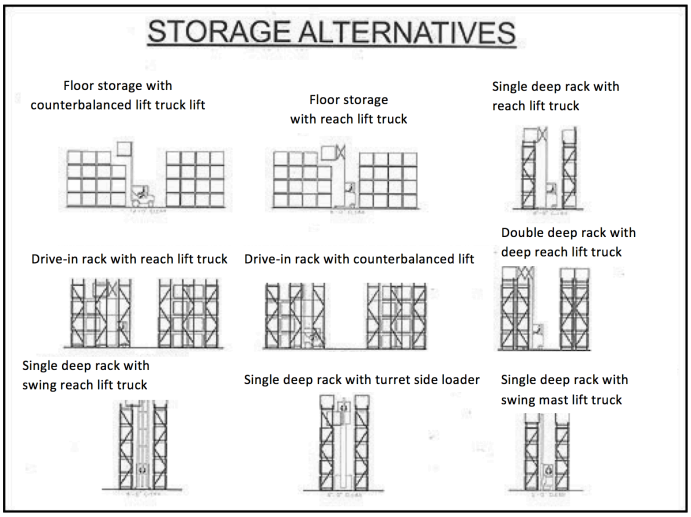


Figure B. 5: Storage alternatives in warehouses (Acker, 2017)

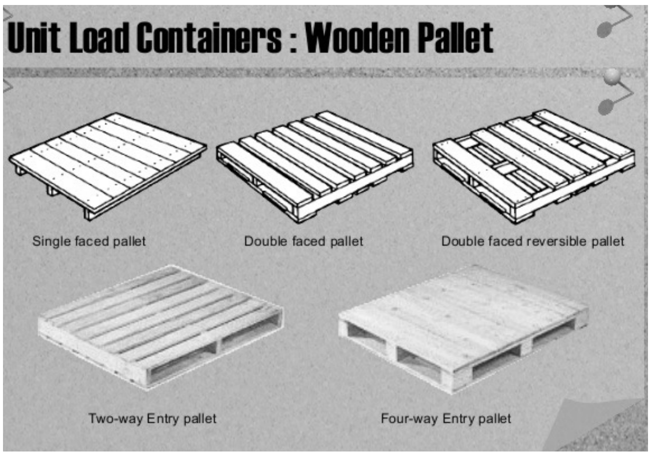


Figure B. 6: Various unit load types (Rahman, 2017)

Analysis tools

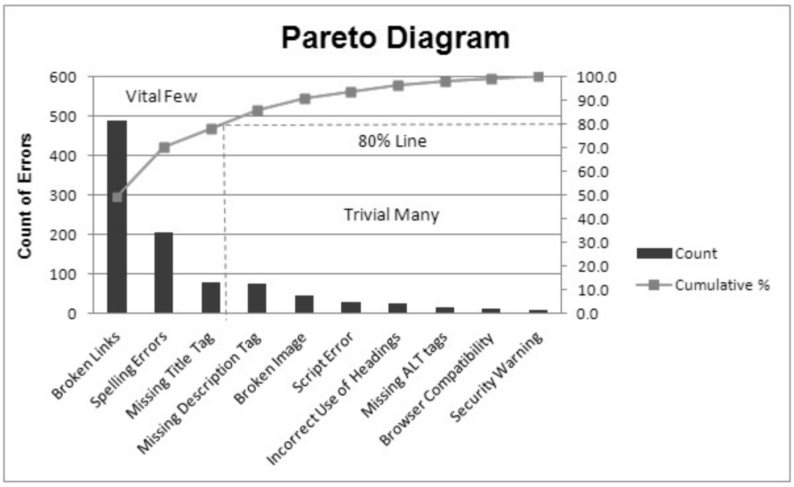


Figure B. 7: Pareto Analysis (80/20 rule) (Haughey, n.d.)

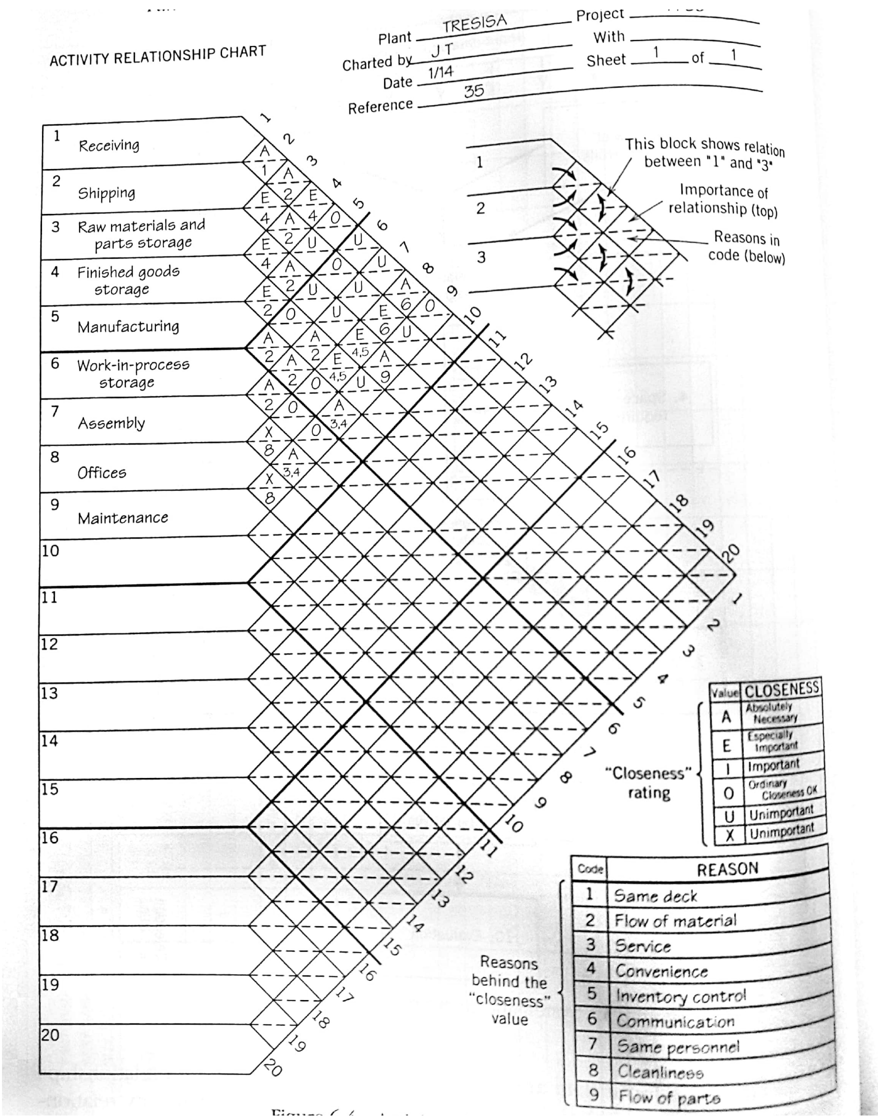


Figure B. 8: Activity Relationship Chart (Tompkins et al, 2010)

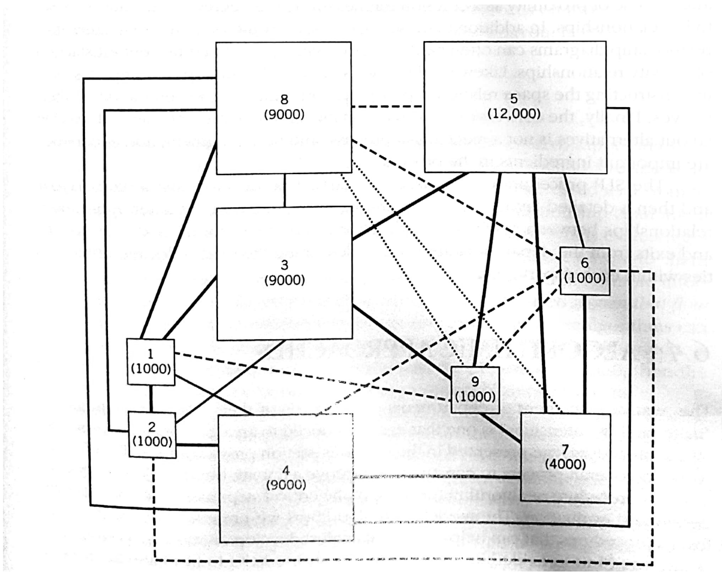


Figure B. 9: Relationship Diagram of the various products or activities (Tompkins et al, 2010)

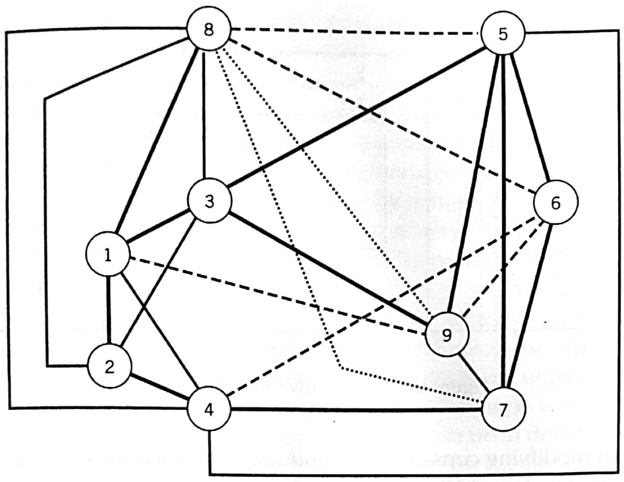


Figure B. 10: Space Relationship Diagram in terms of allocated area (Tompkins et al, 2010)

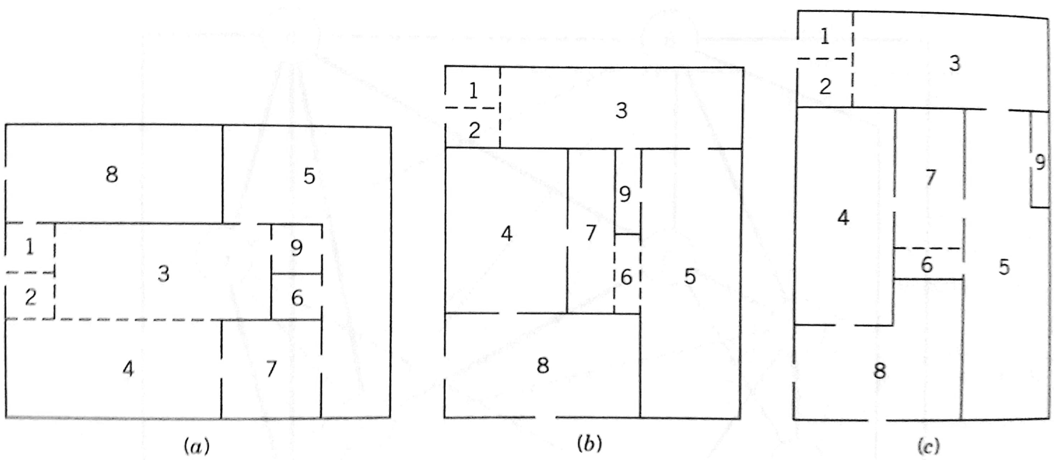


Figure B. 11: Various templates are drawn up as indicated by a, b and c (Tompkins et al, 2010)

Table B. 1: Analysis of the various programs used for warehouse planning and designing

Program	Description	Advantages	Disadvantages
Smartdraw	A CAD design software program that creates plans for facilities, stores, hotels, landscapes, parking lots and many more. The design can be converted to different formats including office applications and PDFs.	• The program is inexpensive and has layouts and templates that range from self-storage units to manufacturing warehouses. • It is also possible to custom make drawings to meet the requirements. • Smartdraw is easy to use and has many elements to choose from. These elements include conveyors, shelves, offices, restrooms, loading docks and a library where images and symbols could be downloaded.	• The user interface does not register on certain small screen computers. • Difficult to navigate in the beginning, but becomes easier through practice. • File folders are not displayed accurately in computer storage.
Warehouse Planner	Developed by Jochen Baumann, a free online software program used for systematic planning of a warehouse. The program creates 3D views, in svg graphic formats.	• Data for material handling could be inserted in the program, such as the dimensions of racks and pallets. • Warehouse planner optimises space by finding creative solutions for storage and equipment. • Aisle widths and standard equipment are given which will aid in the layout of the facility.	• Not a well-known program • Not much additional information given on the program, making it difficult to use the program.
SketchUp	A program developed in 2000 applied by most architects and designers used to generate designs and layouts (Admecindia, n.d.).	• There are various editing tools used to create apartments, warehouses, houses, or any other type of facility. • The program is easy to use and allows for three dimension views. • There are many tutorials, blogs and videos available on the internet if help is needed in a certain area. • Easy access, over 100 000 templates for warehouse designs. • Time-saving compared to other CAD programs.	• The program is not as professional as the others and it limits the design at times, prohibiting the user to customize the sketch.
Chief Architect	A home design software that professionals and architects use.	• The program has automated tools for interior and exterior designs making it user-friendly. • There are built-in-features making the structure of the facilities easy to build. • Drawings could be created with elevations and be displayed in three dimensions. • There are official videos and tutorials on their website or available on YouTube explaining everything the program entails.	• It is quite expensive to purchase the package but could be seen as a future investment, otherwise a free trial period is available. • The program automatic generator of walls and roof could be displayed inaccurately, however this can be edited but could be quite time-consuming.

Appendix C: Concept design

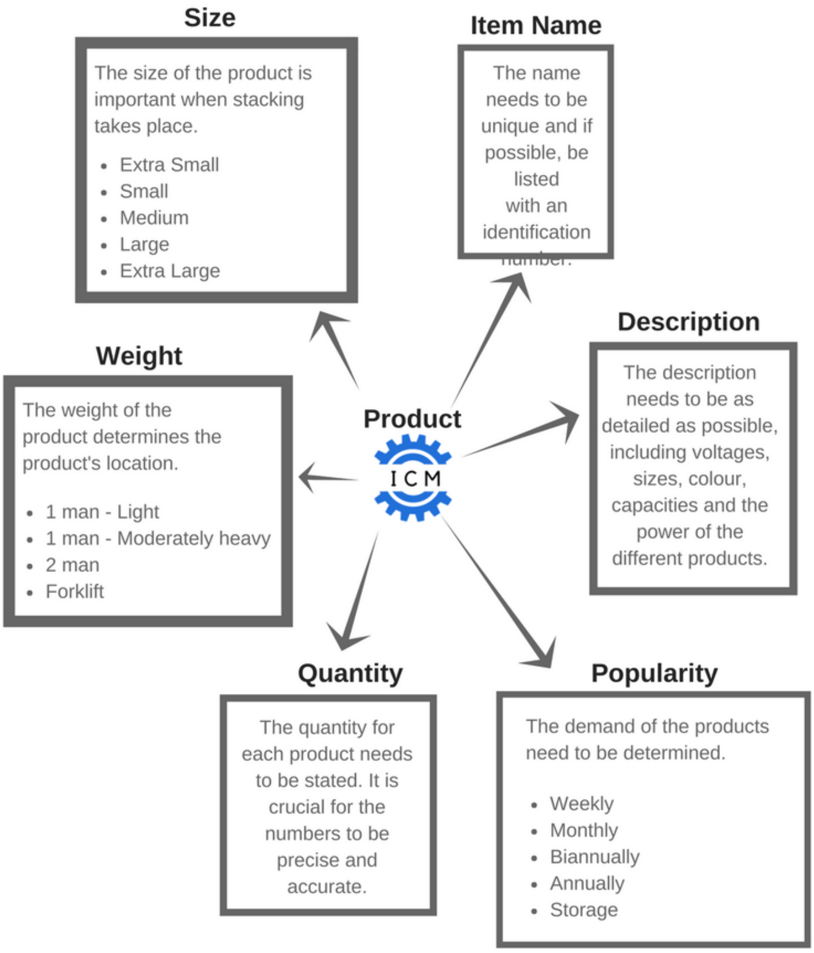


Figure C. 1: Brainstorm of product characteristics

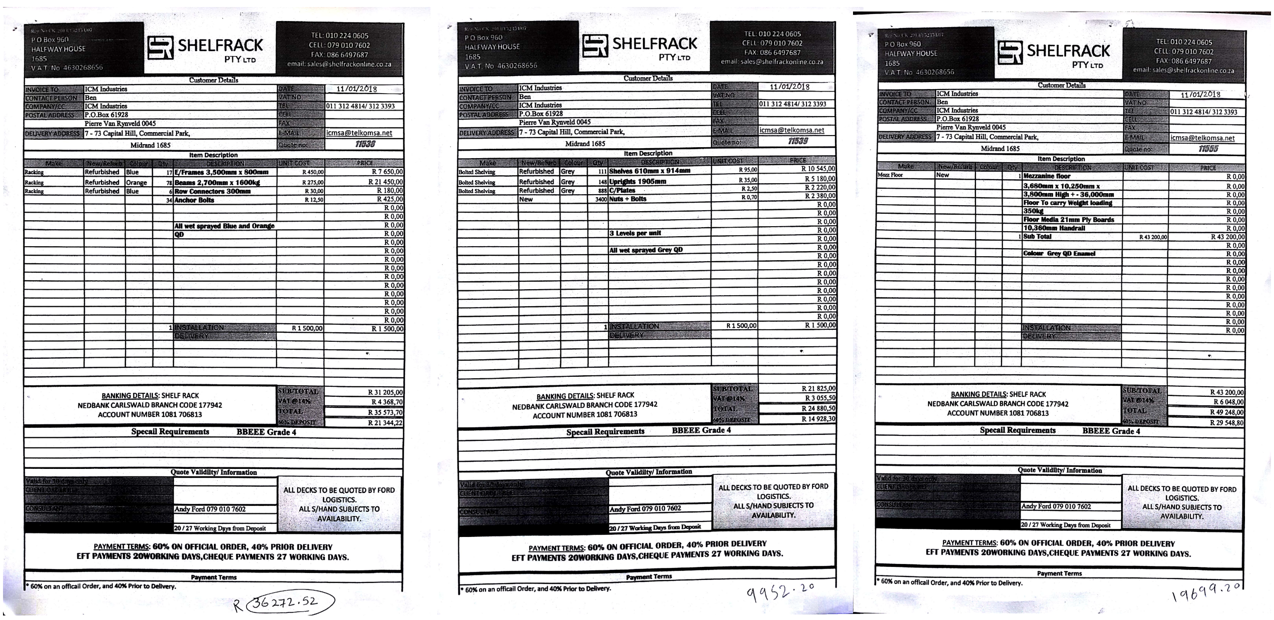


Figure C. 2: Quotes approved for shelving and mezzanine flooring

Appendix D: Model Development

Item Name	Description	popularity	size	weight	Quantity On Hand	Income Account	Cost Account	Inventory Account	Item Type
Chicken Drinker CD10	Chicken Drinker 10L CD10				0	Sales	cost of goods	Inventory Asset	Stock Part
Chicken Drinker CD3	Chicken Drinker 3L CD3				0	Sales	cost of goods	Inventory Asset	Stock Part
Chicken Drinker CD5	Chicken Drinker 5L CD5				0	Sales	cost of goods	Inventory Asset	Stock Part
Chicken Drum Plucker (Extra Fingers)	Chicken Drum Plucker Extra Fingers Each				0	Sales	cost of goods	Inventory Asset	Stock Part
Chicken Drum Plucker PL-50	Chicken Drum Plucker PL-50, 750W	Weekly	Large	2 man	1	Sales	cost of goods	Inventory Asset	Stock Part
Chicken Drum Plucker PL-60	Chicken Drum Plucker PL-60, 2200W	Weekly	Large	2 man	18	Sales	cost of goods	Inventory Asset	Stock Part
Chicken Drum Plucker PL-80	Chicken Drum Plucker PL-80, 4500W				0	Sales	cost of goods	Inventory Asset	Stock Part
Chicken Feeder CF1	Chicken Feeder 1kg CF1				0	Sales	cost of goods	Inventory Asset	Stock Part
Chicken Feeder CF10	Chicken Feeder 10kg CF10				0	Sales	cost of goods	Inventory Asset	Stock Part
Chicken Feeder CF3	Chicken Feeder 3kg CF3				0	Sales	cost of goods	Inventory Asset	Stock Part
Chicken Feeder CF5	Chicken Feeder 5kg CF5				0	Sales	cost of goods	Inventory Asset	Stock Part
Chicken Nipple Drinker CND	Chicken Nipple Drinker CND				0	Sales	cost of goods	Inventory Asset	Stock Part
Chicken Slaughtering Cone	Chicken Slaughtering Cone				0	Sales	cost of goods	Inventory Asset	Stock Part
Chisel Hammer (light duty)	ICM Chisel Hammer for light duty, 1500W, 230V				0	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 1 Pole 10 A	1P 10A (240 pieces in 1 box)	Biannual	Small	1 man - light	10	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 1 Pole 16 A	1P 16A (240 pieces in 1 box)	Biannual	Small	1 man - light	7	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 1 Pole 20 A	1P 20A (240 pieces in 1 box)	Biannual	Small	1 man - light	4	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 1 Pole 25 A	1P 25A (240 pieces in 1 box)	Biannual	Small	1 man - light	3	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 1 Pole 32 A	1P 32A (240 pieces in 1 box)	Biannual	Small	1 man - light	2	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 1 Pole 3KVA	1P 3KA (240 pieces in 1 box)	Biannual	Small	1 man	0	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 1 Pole 40 A	1P 40A (240 pieces in 1 box)	Biannual	Small	1 man - light	4	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 1 Pole 50 A	1P 50A (240 pieces in 1 box)	Biannual	Small	1 man - light	1	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 1 Pole 6 A	1P 6A (240 pieces in 1 box)	Biannual	Small	1 man	0	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 1 Pole 63 A	1P 63A (240 pieces in 1 box)	Biannual	Small	1 man	0	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 1 Pole 6KVA	1P 6KA (240 pieces in 1 box)	Biannual	Small	1 man	0	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 2 Pole 16 A	2P 16A (240 pieces in 1 box)	Biannual	Small	1 man	0	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 2 Pole 20 A	2P 20A (240 pieces in 1 box)	Biannual	Small	1 man - light	3	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 2 Pole 32 A	2P 32A (240 pieces in 1 box)	Biannual	Small	1 man	0	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 2 Pole 30 A		Biannual	Small	1 man - light	3				
Circuit Breaker 2 Pole 40 A	2P 40A (240 pieces in 1 box)	Biannual	Small	1 man - light	1	Sales	cost of goods	Inventory Asset	Stock Part
Ci 2 pole 50		Biannual	Small	1 man - light	1				
Circuit Breaker 2 Pole 63 A	2P 63A (240 pieces in 1 box)	Biannual	Small	1 man - light	1	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 3 Pole 10 A	3P 10A (240 pieces in 1 box)	Biannual	Small	1 man - light	1	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 3 Pole 16 A	3P 16A (240 pieces in 1 box)	Biannual	Small	1 man	0	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 3 Pole 20 A	3P 20A (240 pieces in 1 box)	Biannual	Small	1 man	0	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 3 Pole 25 A	3P 25A (240 pieces in 1 box)	Biannual	Small	1 man	0	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 3 Pole 32 A	3P 32A (240 pieces in 1 box)	Biannual	Small	1 man	0	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 3 Pole 63A	3P 63A (240 pieces in 1 box)	Biannual	Small	1 man - light	1	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 3 Pole 60A	3P 60A (240 pieces in 1 box)	Biannual	Small	1 man - light	2	Sales	cost of goods	Inventory Asset	Stock Part
Circuit Breaker 3 Pole 100 A		Biannual	Small	1 man - light	8				
Circuit Breaker 4 Pole 63A	4P 63A (240 pieces in 1 box)				1	Sales	cost of goods	Inventory Asset	Stock Part
Combined Mobile Van	Combined Mobile Van 1380*670*850 mm				0	Sales	cost of goods	Inventory Asset	Stock Part
Concrete Cutter Blade	ICM 450mm Blade				0	Sales	cost of goods	Inventory Asset	Stock Part
Concrete Cutter Q450	Asphalt or Concrete Cutter Model Q450, 13HP, 450mm				0	Sales	cost of goods	Inventory Asset	Stock Part
Concrete Cutter Q450 (Extra Blade)	Concrete Cutter Extra Blade 450mm				0	Sales	cost of goods	Inventory Asset	Stock Part
Concrete Mixer CM120	ICM CMS120 Wheelbarrow Concrete Mixer, 120L, 370W, 120V - 240V		Large	2 man	1	Sales	cost of goods	Inventory Asset	Stock Part
Construction Bar Bender GW40	Construction Bar Bender GW40, 3KW				0	Sales	cost of goods	Inventory Asset	Stock Part
Control Box 0.75 HP			Small	1 man - light	2				
Control box 0.5 HP			Small	1 man - light	5	Sales	cost of goods	Inventory Asset	Stock Part
Control box 1.1 Hp			Small	1 man - light	3				
Control Box PPB1	3 Phase Protection Box				0	Sales	cost of goods	Inventory Asset	Stock Part
Control Box PPBA1	Automatic Three Phase Controller Box with advanced Protection 0.35 - 2 KW				0	Sales	cost of goods	Inventory Asset	Stock Part
Control Box PPBA5	Automatic Three Phase Controller Box with advanced Protection 5KW				0	Sales	cost of goods	Inventory Asset	Stock Part
Control Box PPBA9	Automatic Three Phase Controller Box with advanced Protection Over 5KW				0	Sales	cost of goods	Inventory Asset	Stock Part
Core Bit - Magnetic 12	Magnetic Core Bit 12mm				0	Sales	cost of goods	Inventory Asset	Stock Part

Figure D. 1: Stock list

Popularity	6	Weekly
	5	Monthly
	4	Quarterly
	3	Biannual
	2	Yearly
	1	Storage
Size	ES	Extra small
	S	Small
	M	Medium
	L	Large
	EL	Extra large
Weight	1	1 man - light
	2	1 man - moderately heavy
	3	2 man
	4	Forklift

Design 1

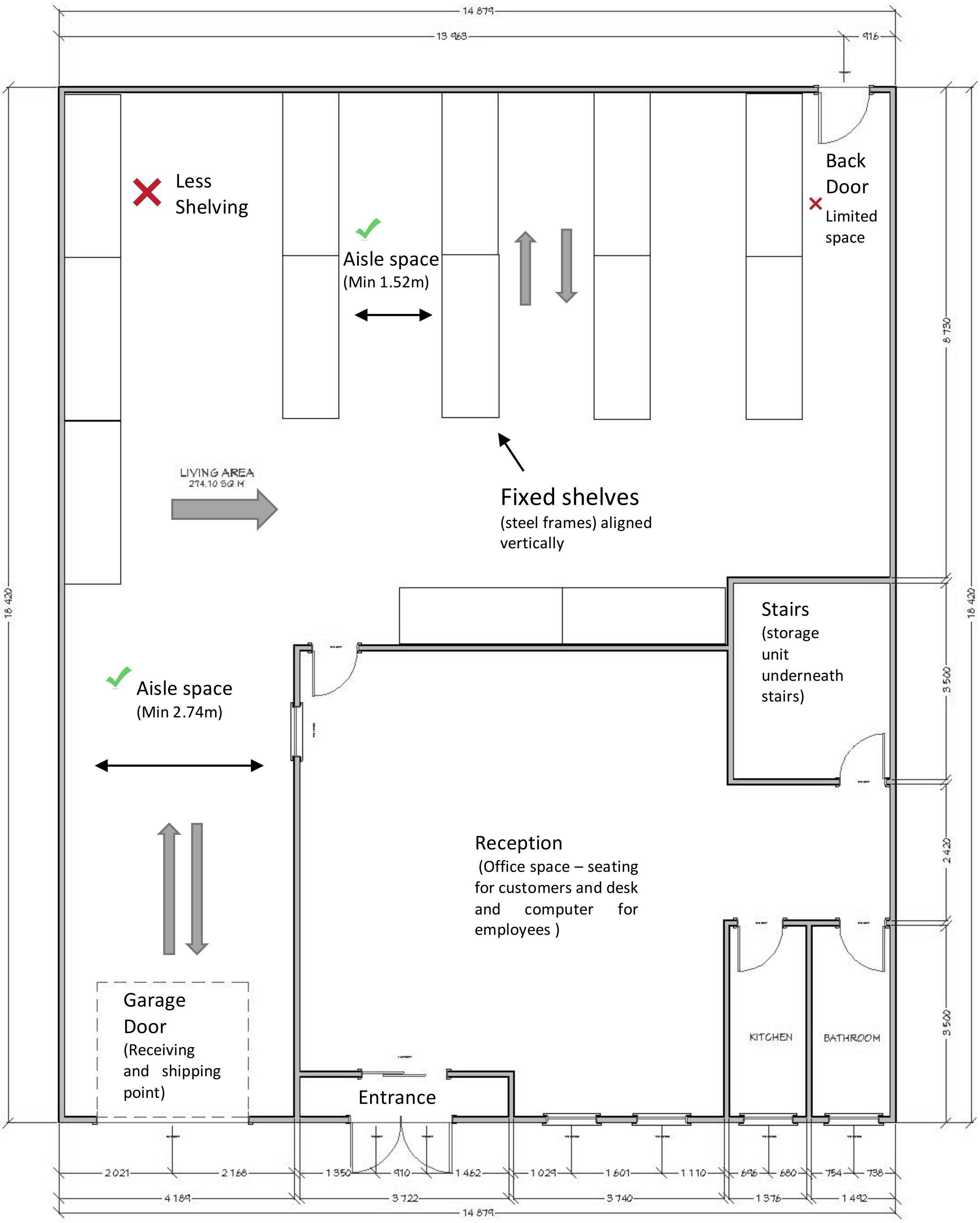


Figure D. 2: Ground floor level of Design 1

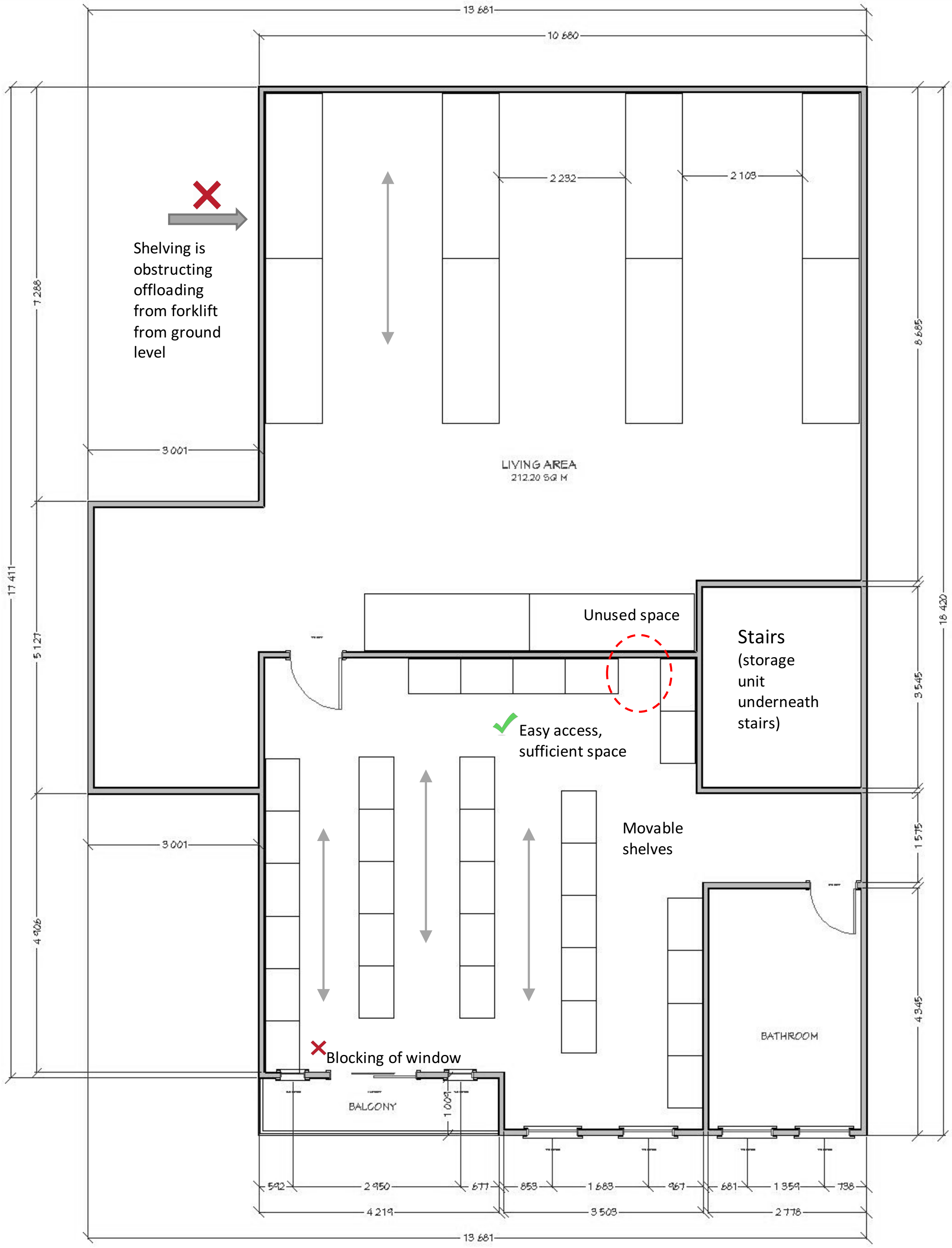


Figure D. 3: Top floor level of Design 1

Design 2

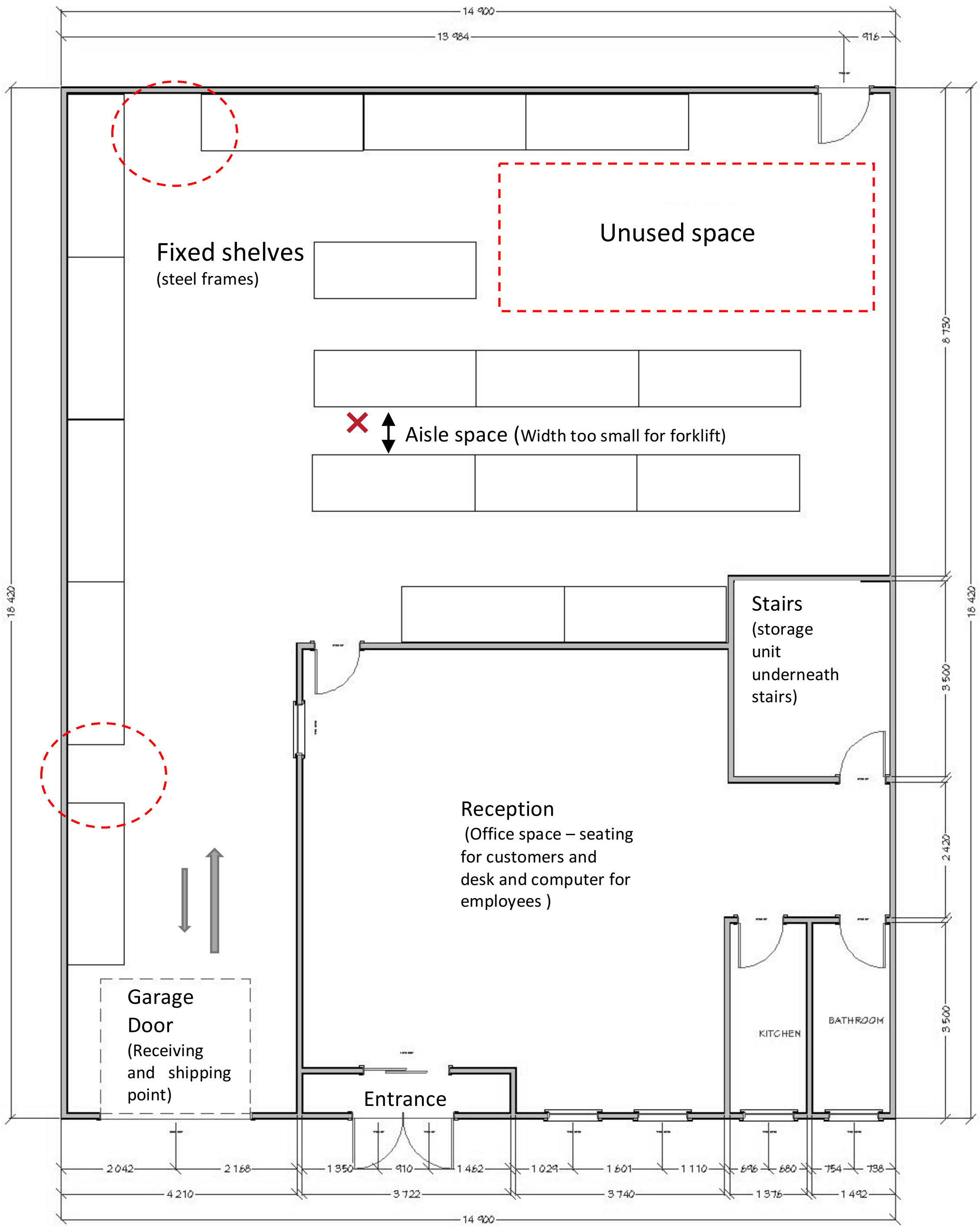


Figure D. 4: Ground level of Design 2

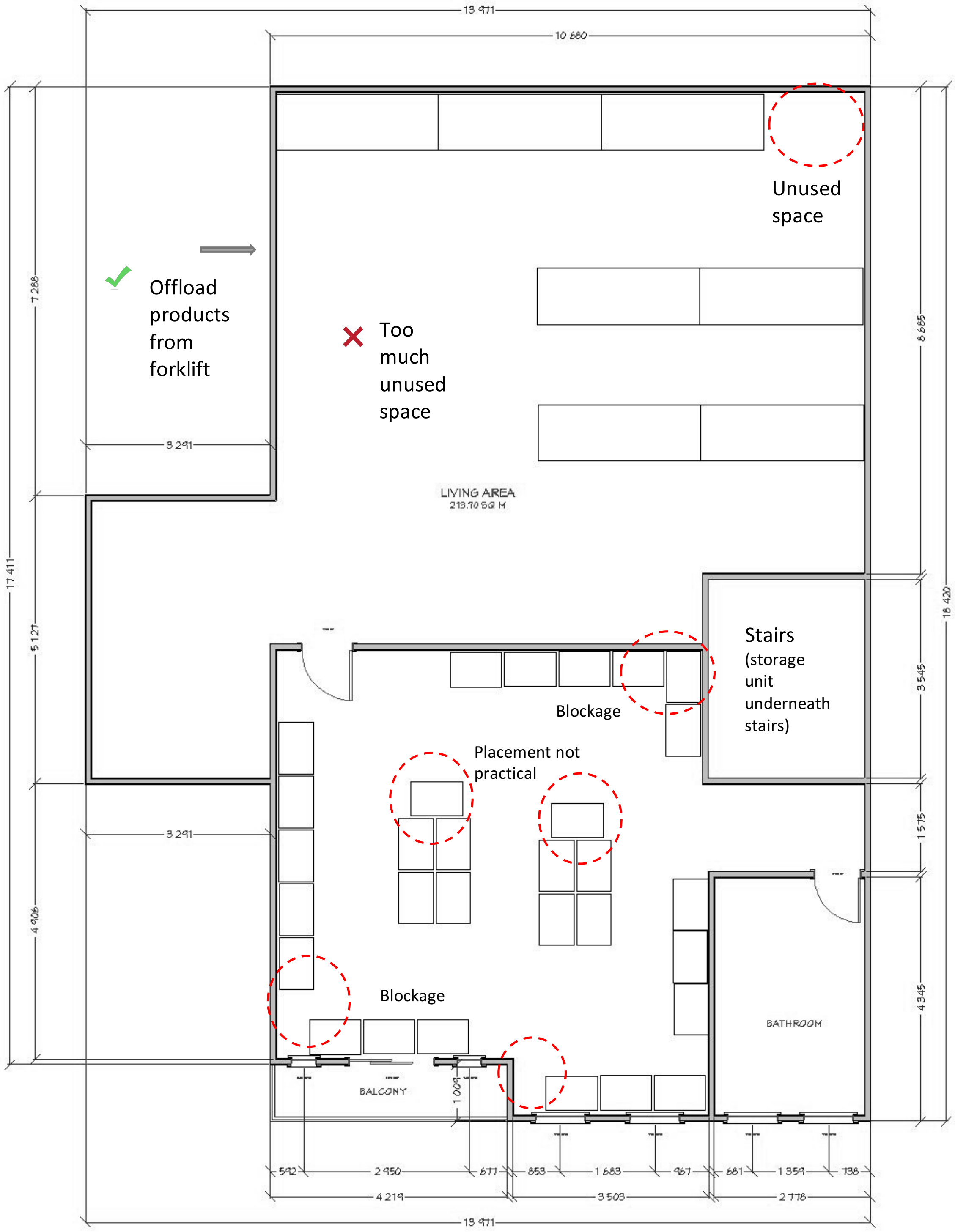


Figure D. 5: Top floor of Design 2

Design 3

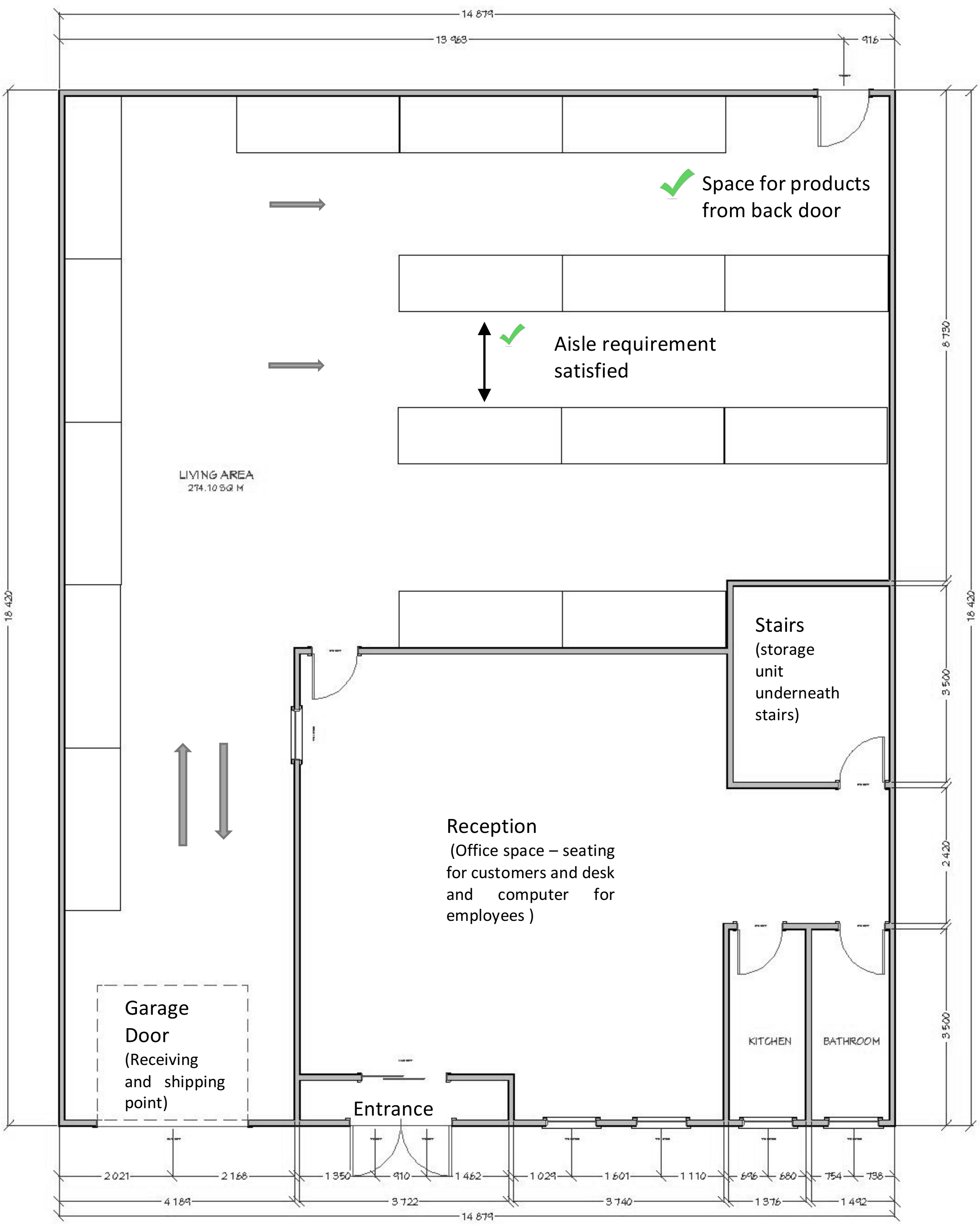


Figure D. 6: Ground level of Design 3

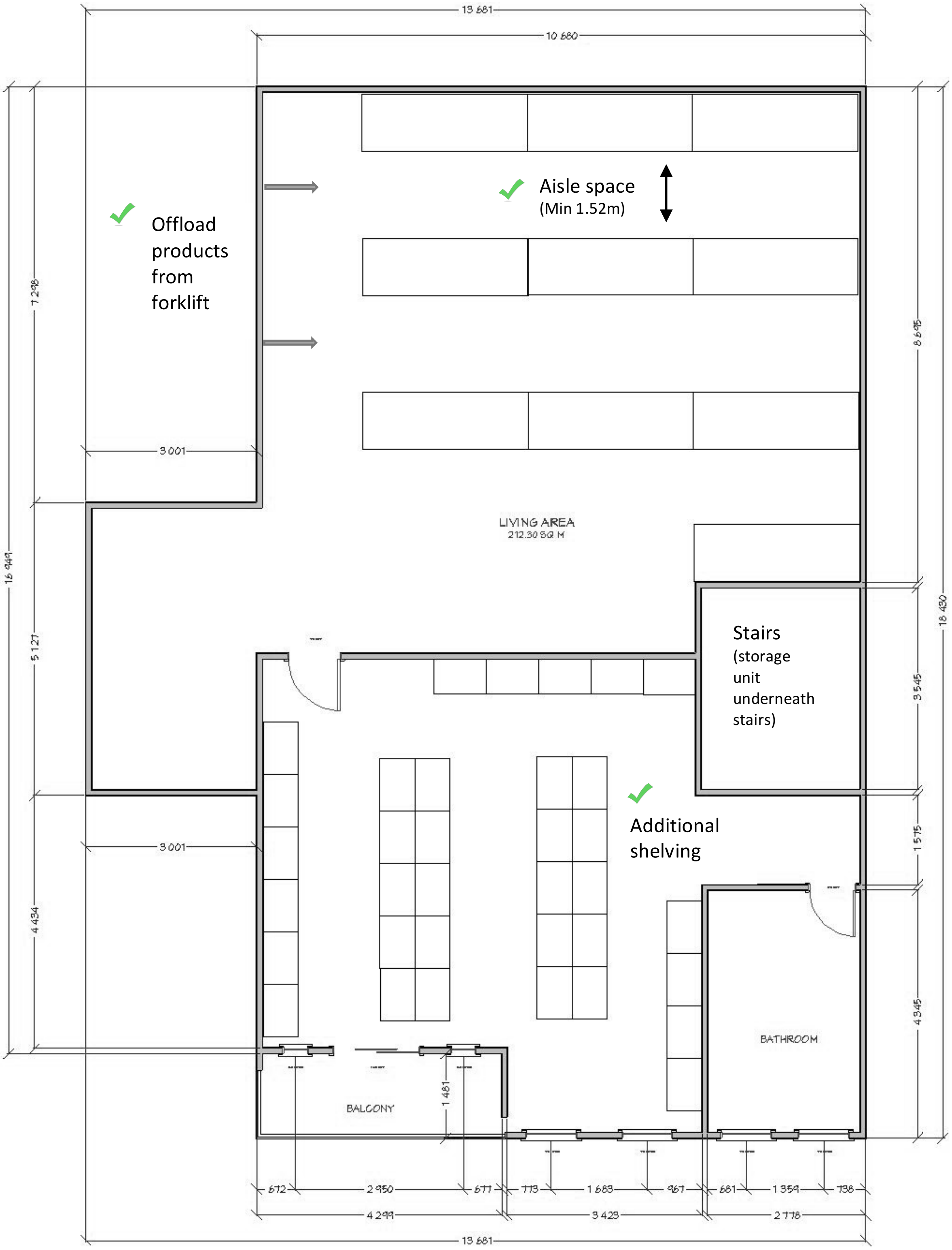
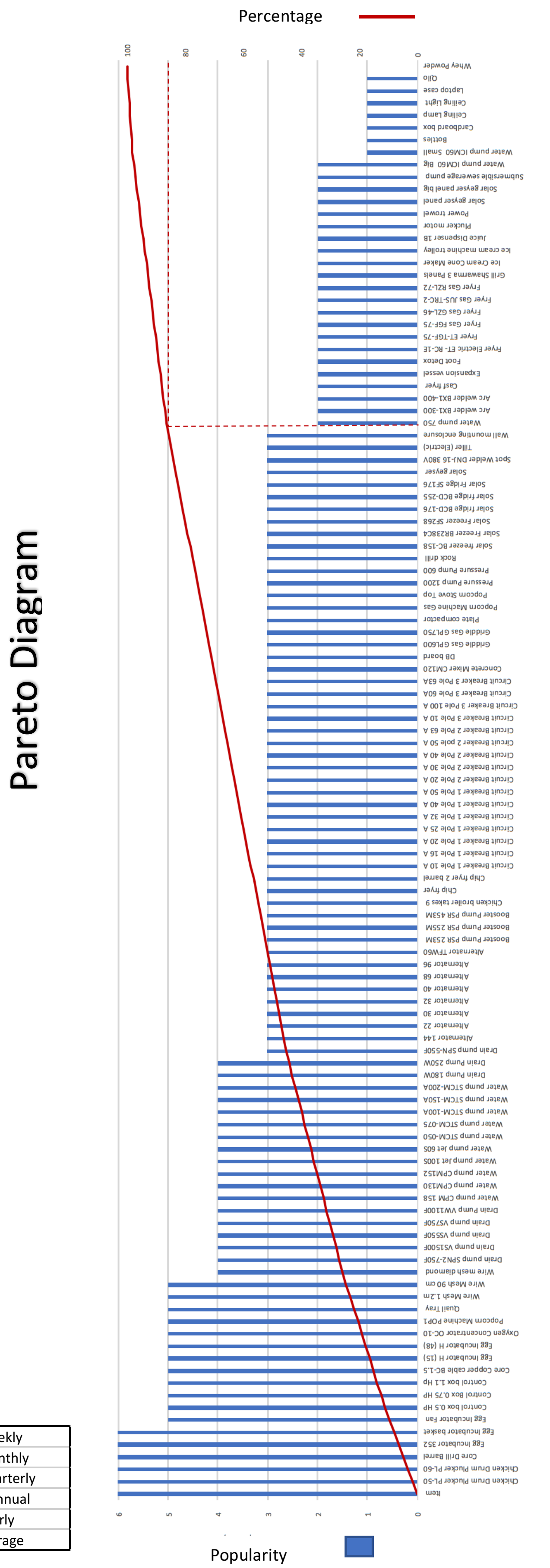


Figure D. 7: Top floor of Design 3



Popularity	6	Weekly
	5	Monthly
	4	Quarterly
	3	Biannual
	2	Yearly
	1	Storage

Figure D. 8: Pareto Analysis

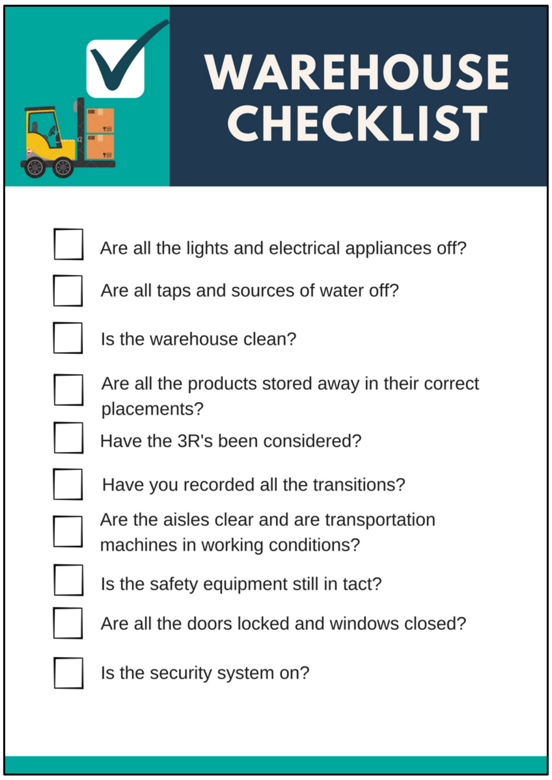


Figure D. 9: Kanban boards

Figure D. 10: Environmental awareness

Figure D. 11: Safety guidelines for the forklift

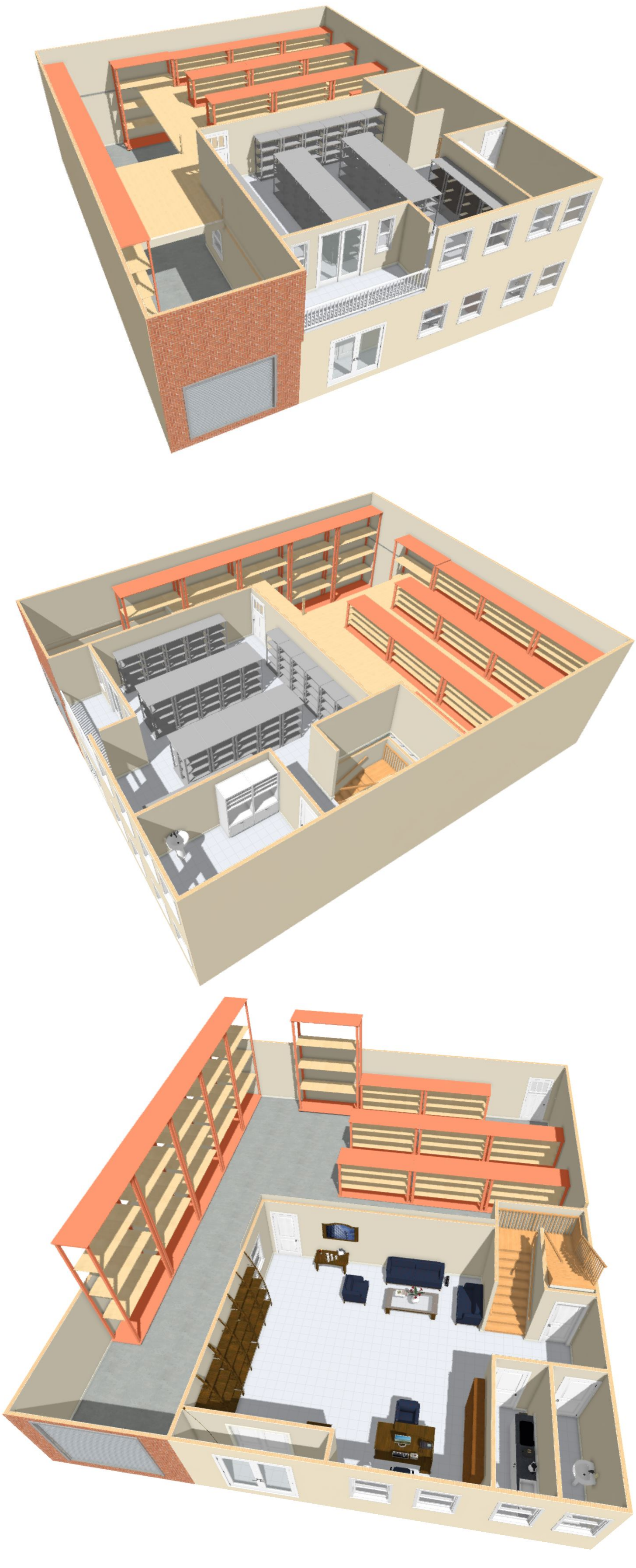


Figure D. 12: 3D Model on Chief Architect

Appendix E: Validation

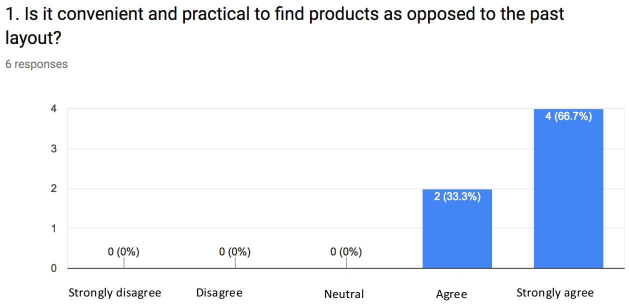


Figure E. 1: Graph indicating convenience and practicality

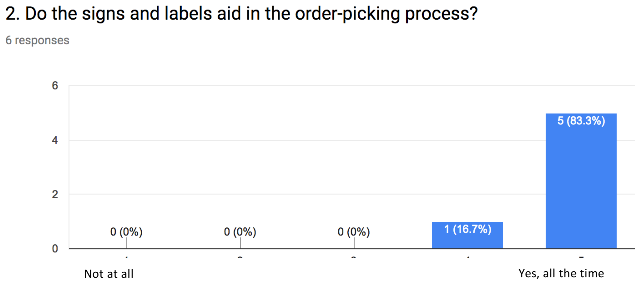


Figure E. 2: Graph showing importance of labels

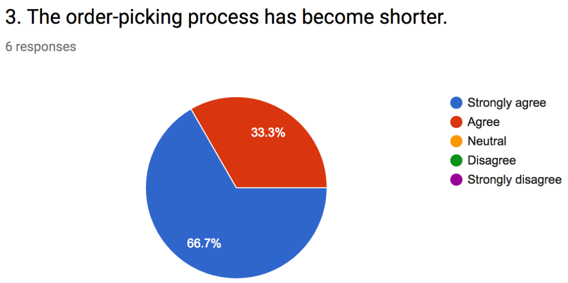


Figure E. 3: Pie chart indicating order-picking time

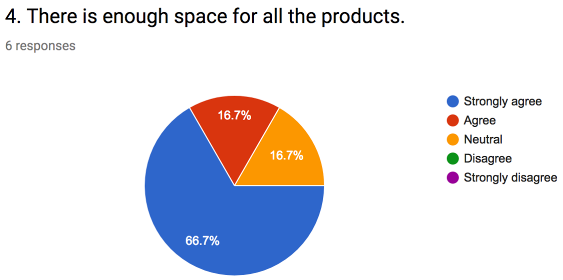


Figure E. 4: Pie chart indicating space used

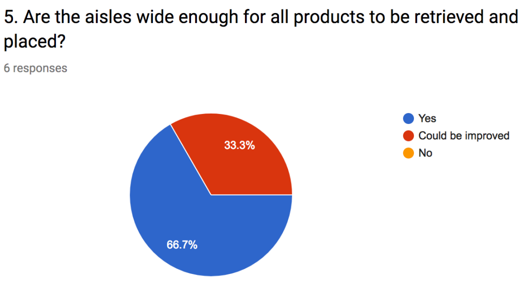


Figure E. 5: Pie chart regarding aisle widths

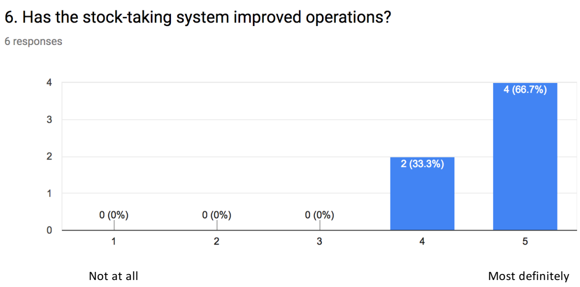


Figure E. 6: Graph displaying improved operations