Facility Planning: An approach to optimise a distribution network at Clover SA

by

ILSE GRASSIE
26033942

Submitted in partial fulfillment of the requirements for the degree of

BACHELORS OF INDUSTRIAL ENGINEERING

in the

FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY

UNIVERSITY OF PRETORIA

October 2009

Executive summary

Clover is the largest dairy company in South Africa with approximately 6500 employees. According to Clover's chief executive, Clover stands for: Stability and their people and producers are 'dairy men' that have milk running through their veins.

The project at hand focuses mainly on facility layout planning and design at Clover's Clayville branch. It involves the building of a chilled warehouse that can meet the company's requirements.

This report systematically explains the aim of the project as well as the extent of it in terms of what will be included and excluded. It includes a study on different approaches that can be followed to design the layout of a facility and contains research on aspects related to facilities planning namely materials handling and materials handling equipment.

The design phase of this project follows Muther's Systematic Layout Planning (SLP) procedure, a methodology that is often used when developing alternative facility layouts. The new proposed facility aims to resolve the distribution network problem which is currently experienced.

Table of Contents: Page

Contents

List of figures Page

List of tables   Page

1. Introduction and background

Clover is a market leader in the dairy industry. According to the company's website, their vision for Clover is: "to be a leading and competitive company in South Africa and selected African countries, reaching every consumer on a daily basis with its most admired branded and trusted products, delivering improved and sustainable shareholder value by being a responsible corporate citizen and preferred employer."

Clover is the largest dairy company in South Africa. They offer various job opportunities to approximately 6500 employees. They inspire their employees to reach their full potential and establish a healthy and ethical work environment.

A graphical representation of Clover's organisational structure can be seen below.

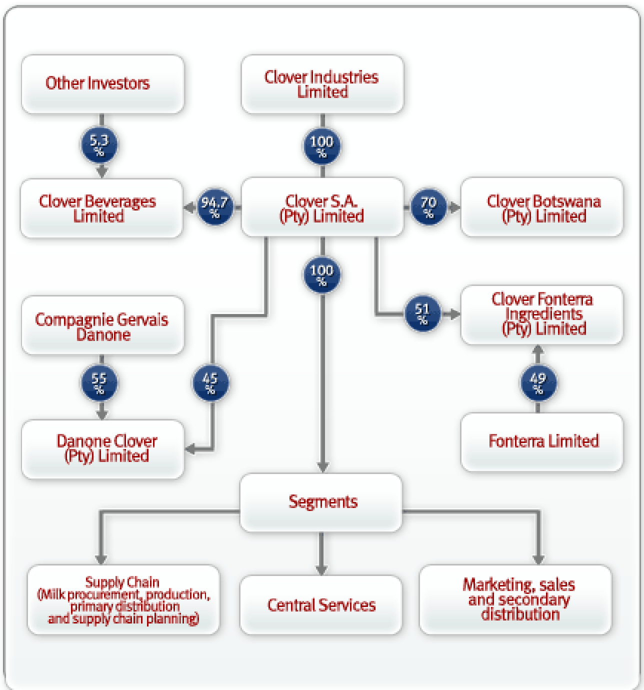


Figure 1: Organisational structure

Clover is a Fast Moving Consumer Goods (FMCG) company and has about 400 of their own branded products available on the market that is produced and packaged at one of their factories. They also carry inventory and distribute approximately 200 products for other principals. This means that, effectively, they manage 600 different types of products on a daily basis.

Clover's larger branches are situated in City Deep, Cape Town, Queensburgh, Clayville, Boksburg and Port Elizabeth. Some of their other, smaller branches include areas such as: East London, Kimberley, Welkom, Bloemfontein, Potchefstroom, Nelspruit, George, Polokwane, Upington, Port Shepstone, Kokstad and Newcastle. This project will focus on the Clayville branch.

Production of fresh milk and UHT (Ultra High Temperature) milk takes place at the two factories that are situated at the Clayville site. The existing warehouses at Clayville are small and can not pick and store the required volumes of the products that are produced on site for the 16 warehouses all around the country and because of this all the products that are produced have to be distributed to other warehouses in Gauteng where it is stored and picked for the remaining warehouses. The problem with this operating method is that it places the current distribution network under pressure, creates more double handling and increased distribution cost.

The lack of picking space at Clayville also results in them only being able to pick full pallets of products and not all products manufactured over a 24 hour period, this results in over-stocking of branches with stock they do not necessarily require. This causes the problem that the other warehouses, that are sometimes already struggling to manage their existing volumes, do not have storage room available for the new stock. As a result, warehouse and stock management requires more attention.

It also happens that products are distributed to the wrong warehouses by mistake. Most of Clover's other sites do not have room for expansion.

If this distribution network problem can be solved it will have multiple benefits for the company that includes reduced distribution cost, reduced inventory, reduced double handling and room to grow.

According to the third edition of *Facilities Planning* by Tompkins, White, Bozer and Tanchoco, facilities planning is no longer just a science, but a strategy for navigating a competitive global economy.

2. Project Aim

The aim of the project is to reduce the strain on Clover's current distribution network by planning and building a chilled warehouse at the Clayville site that will be able to handle the future required volumes.

By achieving **the objectives** listed below the aim of the project will be realised.

- Reduced inventory.
- Reducing capacity constraints at the other warehouses.
- Reducing pressure on the warehouse and stock planners.
- Reduced distribution costs.

Clover
It's all you need

3. Project Scope

The project will be based on the following:

- Building a new chilled warehouse next door to the current fresh milk factory.

The scope of the project will include a high-level planning of:

- Inventory storage requirements.
- The layout of the new chilled warehouse that will be built.
- The personnel requirements.
- The equipment requirements.
- The warehouse management system equipment requirements.

Lots of attention will be focused on the layout planning, which will include:

- Analysing future volumes that the facility must handle
- Aisle widths
- The amount of dispatch cages
- The receiving areas
- Picking areas / storage area
- Allocation of space for the battery and plant rooms
- Offices

The equipment requirements will include determining the amount of forklifts, reach trucks and power pallet trucks that the facility will need, according to the workload of the required facility.

Clover
It's all you need

The equipment requirements will influence the personnel requirements since each forklift, reach truck and power pallet truck will need a driver. The amount of checkers, pickers and supervisors will also have to be determined.

The warehouse management system equipment includes the scanners, that tell the above equipment drivers and other warehouse staff what to do, as well as the computers needed to manage the warehouse.

Data analysis will have to be done in depth before the layout or any other requirements can be determined. Data analysis will thus be a critical part of the project.

The following will not be included in the project scope:

- The detail of the battery and plant rooms
- Chilling requirements
- Fire protection
- Electrical requirements
- A parking area for the delivery trucks
- Ablution blocks
- A canteen for employees

4. Literature review

4.1 Facilities planning defined

Even though facilities planning is a popular topic that has been taught and studied for more than 50 years, it is still challenging and in some ways mysterious. The subject of facilities planning is very wide-ranging and intricate. According to Tompkins (Tompkins et al, 1984), facilities planning is, in spite if its heritage, still one of the most well-liked subjects of seminars, publications and research.

According to Tompkins (Tompkins et al, 1984): "*Facilities planning determines how an activity's tangible fixed assets best support achieving the activity's objectives.*"

Facilities planning is not a static process. It continues to change due to new methodologies that develop as a result of changes in technology. According to Tompkins (Tompkins et al, 1984), it is part art and part science. They divide facilities planning into two fields, namely facilities location and facilities design. Facilities design is then separated into three components namely the structure, layout and handling system.

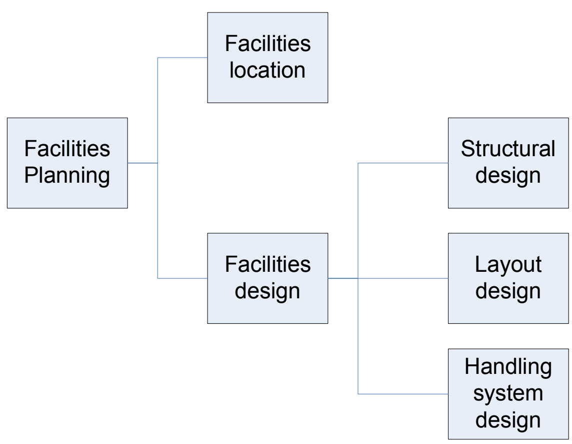


Figure 2: Facilities planning hierarchy

According to Tompkins (Tompkins et al, 2003), the following are common triggers or reasons that might urge a company to redesign the layout of a facility:

- Changes in legal requirements, for example environmental requirements, by the state
- Changes in their operating methods, processes or equipment
- Changes in the volume or mix of the outputs of products that is required
- Changes in the design of the company's product(s) or services
- Introduction of new products or services
- High operating costs, occurrence of bottlenecks in the system or unnecessary excessive handling of products
- Safety hazards or increase in the amount of accidents reported
- Morale problems amongst staff, that influence teamwork, or between staff and customers (lack of face-to-face contact)

4.2 Significance of Facilities Planning

Facilities planning and design forms part of a company's strategic planning. The strategic importance thereof lies largely in the fact that substantial investments have to be made in the facility planning field in order to upgrade existing facilities and build new facilities, to maintain a certain standard.

The design and layout of a facility have a major impact on aspects such as operating costs, material handling costs, maintenance, management and control of the facility, adaptability and flexibility of processes and employees, employee morale and productivity according to Tompkins (Tompkins et al, 2003).

Facility planning creates opportunities for cost reduction and productivity improvement. Continuous layout changes and rearrangement of activities is necessary in order to comply with regulations such as employee health and safety and disability. It is also required due to changes in technology, environmental impact and conservation of energy and other resources.

4.3 Basic layout types

Tompkins (Tompkins et al, 1984) identified four types of planning departments namely:

- Fixed material location departments
- Production line departments
- Product family departments
- Process departments

A journal, "Facilities design using a split departmental layout configuration" published by Professor B. Gopalakrishnan and two graduate students of West Virginia University, classifies factory layouts as the following:

- Fixed position layout
- Process oriented layout (also known as a job shop)
- Group or cellular layout
- Product oriented layout (also known as a flow shop)

The type of layout chosen by a company is dependent on the kind of activities that the facility will be used for, as well as the volume and variety of products.

4.4 Layout Procedures

As mentioned earlier facilities planning is not a static process. Even though a facility is only planned once, it is often revised and adjusted according to the changing needs of the facility in order to align the layout with the objectives and requirements set for the facility. Tompkins (Tompkins et al, 1984), sees this as having a facilities life cycle.

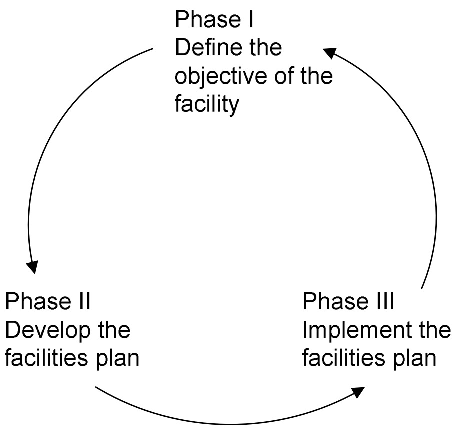


Figure 3: The facilities life cycle

Tompkins (Tompkins et al, 1984), believes in an organized, systematic approach namely, "*the engineering design process".* This process consists of 10 steps, listed below:

4.4.1 The engineering design process

1. Define (or redefine) the objective of the facility.
2. Specify the primary and support activities to be performed in accomplishing the objective.
3. Determine the interrelationships among all activities.
4. Determine the space requirements for all activities.
5. Generate alternative facility layouts.

6. Evaluate alternative facility layouts.
7. Select a facility layout.
8. Implement the facility layout.
9. Maintain and adapt the facility layout.
10. Redefine the objective of the facility (in the case where changes have to be implemented).

A variety of alternative procedures exist that can be used to develop the layout of a facility. The following are a few examples that Tompkins (Tompkins et al, 1984), has reviewed and that will be discussed in this document:

- Immer's basic layout planning steps
- Nadler's ideal systems approach
- Systematic layout planning by Muther
- Apple's plant layout procedure
- Reed's plant layout procedure

4.4.2 Immer's Basic Layout Planning Steps

This approach, entailing the basic steps in the analysis of a layout, was published by Immer in one of the first books that was dedicated to the subject of facility layout planning. Immer stated that, "This analysis should be composed of three simple steps, which can be applied to any type of layout problem." The 3 steps are:

1. Put the problem on paper.
2. Show lines of flow.
3. Convert flow lines to machine lines.

This approach by Immer focuses on and thus works best, when you have an existing layout that needs to be improved or adjusted to meet new objectives and requirements. It does not make provision for the planning of new facilities.

4.4.3 Nadler's Ideal Systems Approach

The *ideal systems approach* should rather be seen as a philosophy than an approach. When Nadler presented this approach it was meant for designing work systems, but it is vastly relevant to facilities planning. Nadler's approach follows the sequence below:

1. *Aim* for the "theoretical ideal system."
2. *Conceptualize* the "ultimate ideal system."
3. *Design* the "technologically workable ideal system."
4. *Install* the "recommended system."

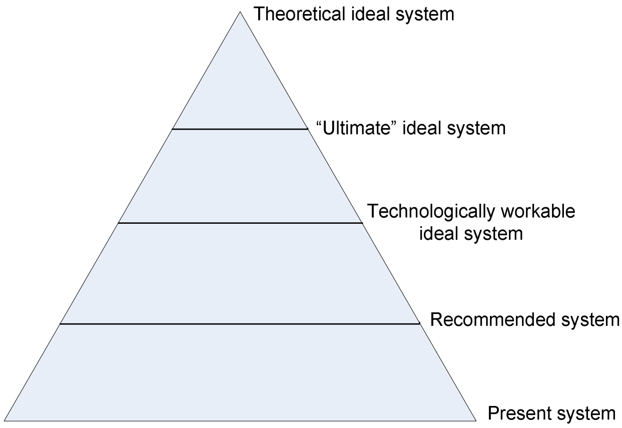


Figure 4: The hierarchical ideal systems approach

With this approach one starts at the top with a "theoretically best" and work your way down to the "recommended practical design." Nadler wants the way of thinking to change from "what has been" to "what can be." Immer focuses on the opposite of what is suggested by Nadler.

4.4.4 Systematic layout planning by Muther

This layout procedure that was developed by Muther in 1973 is very popular and is frequently used. It is also in short referred to as SLP. A framework for SLP can be seen on the following page.

According to Tompkins (Tompkins et al, 2003), the process involved in executing SLP is fairly uncomplicated. This does not necessarily mean that no complexities will occur in the application of SLP.

When using the SLP approach a block layout is first developed before there can be continued to a detailed layout for each department.

This process requires the facility planner to develop many different charts and diagrams. This can be seen as an advantage of this process since people tend to understand a process more easily if they can visualize it. The charts and diagrams that are constructed during this procedure, as well as the function of each, are listed below:

- From-to chart: used to quantitatively measure flows in terms of the amount moved between departments.
- Activity relationship chart: determine the relationship between departments and the importance thereof.
- Relationship diagram: positions activities where they are actually located in a two-dimensional space.
- Space relationship diagram: same as relationship diagram, only with the space of each department included.

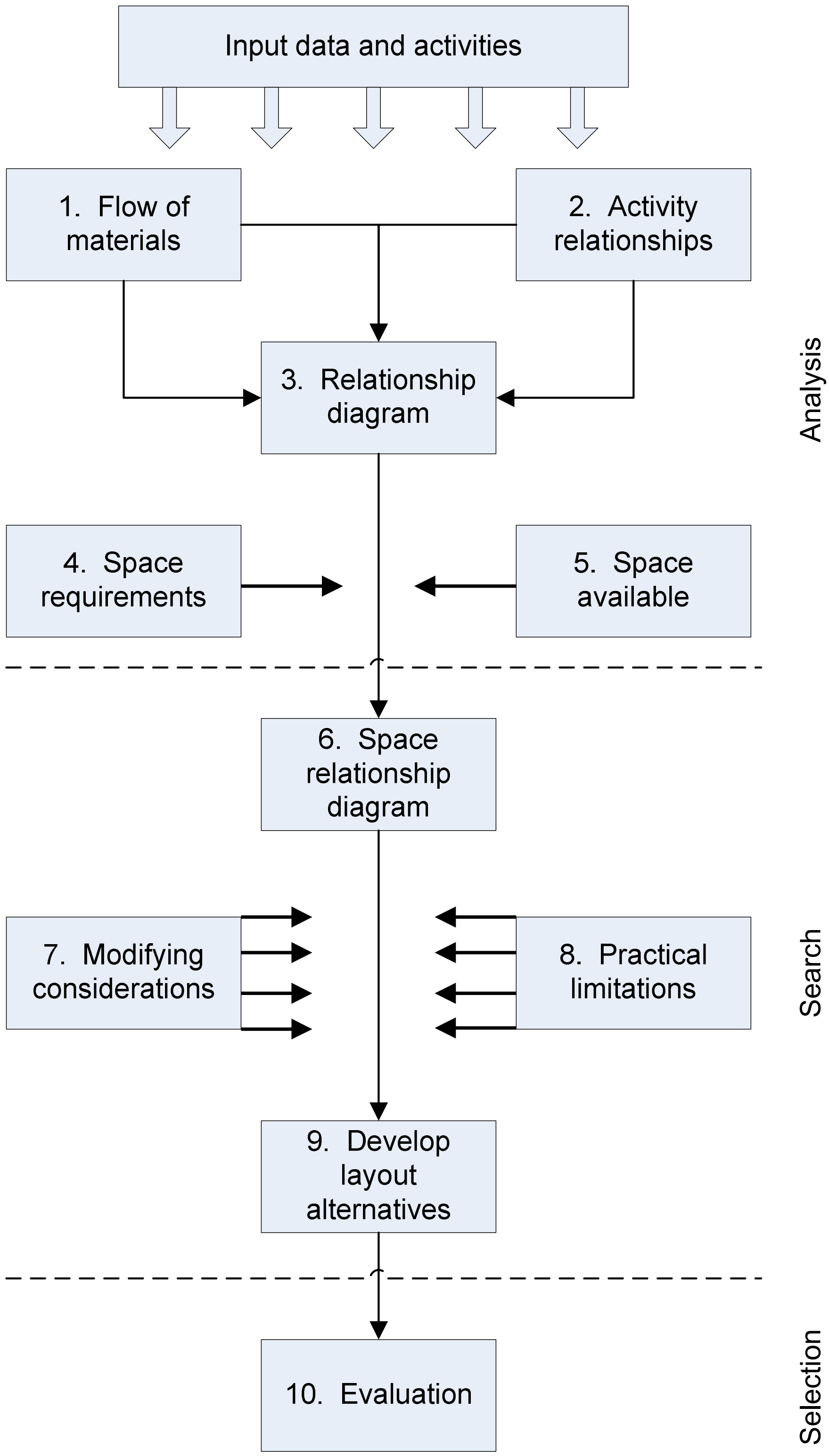


Figure 5: Systematic layout planning (SLP) procedure

According to Tompkins (Tompkins et al, 1984), the activity relationship chart is used as the basis of SLP. A material flow analysis (in the form of the from-to chart) and an activity relationship analysis (in the form of an activity relationship chart) can be done once an understanding have been reached of the input data and the roles and relationships between activities. From there a relationship diagram can be constructed and later on the space relationship diagram.

4.4.5 Apple's Plant Layout Procedure

Apple developed a sequence of 20 steps which he recommended be used when aiming to construct a plant layout. According to Apple the steps do not necessarily have to be performed in the order that it is given, since the design of every layout project is unique. The steps are as follows:

1. Procure the basic data.
2. Analyse the basic data.
3. Design the productive process.
4. Plan the material flow pattern.
5. Consider the general material handling plan.
6. Calculate equipment requirements.
7. Plan individual workstations.
8. Select specific material handling equipment.
9. Coordinate groups of related operations.
10. Design activity interrelationships.
11. Determine storage requirements.
12. Plan service and auxiliary activities.
13. Determine space requirements.
14. Allocate activities to total space.
15. Consider building types.
16. Construct master layout.

17. Evaluate, adjust and check the layout with the appropriate persons.
18. Obtain approvals.
19. Install the layout.
20. Follow up on implementation of the layout.

4.4.6 Reed's Plant Layout

According to Tompkins (Tompkins et al, 1984), Reed developed steps, which he referred to as a "systematic plan of attack", to be used for the planning and preparation of a facility's layout. The ten steps are listed below:

1. Analyse the product or products to be produced.
2. Determine the process required to manufacture the product.
3. Prepare layout planning charts.
4. Determine workstations.
5. Analyse storage area requirements.
6. Establish minimum aisle widths.
7. Establish office requirements.
8. Consider personnel facilities and services.
9. Survey plant services.
10. Provide for future expansion.

Reed considers step 3, the layout planning chart, as the most crucial part of the total layout process. The layout planning chart integrates five important factors namely:

1. The flow process, including operations, transportations, storage and inspections.
2. Standard times for each operation.
3. Machine selection and balance.
4. Manpower selection and balance.
5. Material handling requirements.

4.5 Strategic facility planning

As mentioned previously, facilities planning and design forms part of a company's strategic planning. According to the journal "Strategic facility planning (SFP)" by Frank Kerns, a company's facilities are believed to be part of their most valuable and noticeable assets. He believes that the following are elements that should be considered when designing a future facility:

- custom designed to meet customer needs;
- designed to facilitate time compression;
- flexible to allow adjustments to meet rapid market changes;
- ability to accommodate fast to market new products;
- focused for a small range of products;
- designed for a flat organization;
- planned at the lowest possible level;
- linking suppliers, manufacturing and customers;
- managed by a few "managers" facilitating decision making;
- training to adapt to change.

According to Frank Kerns, strategic facility planning uses a seven-step approach when used in its most uncomplicated form. The seven steps are similar to Muther's systematic layout planning approach and are listed below:

1. Identify space planning identifiers (SPI's)
2. Chart the affinities/relationships
3. Determine space requirements
4. Develop layout primitive
5. Generate macro layouts
6. Evaluate layouts
7. Populate layout

The strategic facility planning approach looks at facility planning and design with customer value in mind. It encourages a company to effectively use their resources to gain a competitive advantage by satisfying the customer's requirements.

4.6 Related aspects

Facility planning is closely related to several of a company's operational activities. These activities have to be taken in to account when deciding on a facility designing approach and is thus included as part of the literature review.

4.6.1 Materials handling

Materials handling is one activity that goes hand in hand with facility planning. A company's materials handling method has to be compatible with the layout of the facility.

Materials handling can be defined as both an art and a science. It entails not only the moving of material but also the storing, controlling and protecting thereof (Tompkins, Tompkins et al, 2003).

Material handling can also be described by the nine R's namely, providing the:

1. Right amount of the
2. Right material in the
3. Right condition at the
4. Right place in the
5. Right position at the
6. Right time in the
7. Right sequence and for the

8. Right cost by the
9. Right method(s)

Tompkins (Tompkins et al, 2003) classifies the following as the objectives of material handling:

- Improving the utilisation of the facility.
- Increasing productivity.
- Improving working conditions and safety of workers.
- Increasing the efficiency of the flow of materials through the facility.
- Reducing the cost of material handling.
- Facilitating the manufacturing process.

Material handling is expensive and accordingly requires a large amount of planning and attention. According to Tompkins (Tompkins et al, 1984) it is difficult to measure the precise cost of material handling but in general it usually accounts for 8% up to 10% of the total cost of a business depending on the type of facility.

4.6.2 Materials handling equipment

Material handling equipment in turn goes hand in hand with material handling. The type of activities that the facility will be used for determines the type of equipment required. Certain material handling methods require certain equipment. This project involves the development of a chilled warehouse, thus there will be focused on warehouse materials handling equipment.

The types of equipment that are usually used in a warehouse include hand pallet trucks, pallet trucks, pallet stackers, reach trucks, order pickers, very narrow aisle trucks, tow tractors and forklift trucks. Images of an electric pallet truck, a forklift, a hand pallet truck and a reach truck can be seen below:

Figure 6: Electric pallet truck

Figure 7: Forklift

Figure 8: Hand pallet truck

Figure 9: Reach truck

Numerous different approaches to facility planning and design have been developed over the past few years. Facility planning can become quite complex when all related activities, such as materials handling, are taken in to account. An approach that complies with the needs of this specific project will be chosen based on the above study, and it will be followed in order to successfully complete the project at hand.

5. Conceptual design

The concept and plan that will be followed in order to successfully carry out the project and meet the specified aim and objectives are as follows:

5.1 Data Analysis

In order to achieve the aim and objectives of the project the available data has to be studied in depth. The data has to be analysed and a clear understanding must be reached of the requirements that exist as a result of the available data. The data analysis will require that certain calculations be done and answers will need to be round up or down depending on what is being calculated. If the data is not clearly understood the project aim and objectives might become elusive.

5.2 Facility layout design

Based on the literature review that was done, the systematic layout planning approach by Muther could be used to develop several alternatives for the layout of the new chilled warehouse. Muther's SLP approach is well known and very popular and has been proven to work effectively in the designing of facility layouts. All the diagrams required by SLP will be constructed based on Clover's needs at their Clayville branch. This part of the project is seen as the most important phase.

5.3 Material handling and equipment

Once the designing of the layout of the facility is done, material handling and material handling equipment will be given some attention since it is related to facility planning and will be influenced by the layout of the facility. The material handling system of the warehouse is not included as part of the scope of the project and thus will not be discussed in detail.

The abovementioned phases give a high-level idea of the concept and plan that will be followed throughout the project. Each phase requires various inputs to get a certain required outputs. The phases have several sub phases that will have to be completed before there can be continued to the next phase.

6. Data and information gathering and analysis

As mentioned earlier, based on the literature review that was done, the systematic layout planning approach by Muther will be used to develop several alternatives for the layout of the new chilled warehouse.

The departments that were identified to be used in the SLP process are the following:

- Receiving area
- Storage/picking area
- Stage area
- Dock cubicles
- Offices
- Battery room
- Plant room

The requirements for each of the abovementioned departments are dependant on the throughput of the facility. The necessary available product data that will determine the throughput thus have to be collected before attending to the individual departments.

It is clear that lots of information need to be obtained before starting with the steps of Muther's systematic layout planning approach.

6.1 Available product data

The data that were available for each product that will be stored and dispatched from the facility are listed below and can be seen in Appendix A of this document.

- The SKU number of the product
- The temperature zone of the product (i.e. whether the product is chilled or ambient)
- The amount of kilograms of the specific product that fits on to a pallet
- The volume, in kilograms, that will be handled by the facility every month
- The amount of days' stock of each product that they usually keep in their warehouses. Since Clover is a fast moving consumer goods company (FMCG) and their products are perishable they are not able to keep great amounts of inventory.
- Whether the product is stored in a case or crate
- Whether the product is produced in the factory on the Clayville site (internally) or is delivered from one of Clover's other factories (externally).

Please note that the assumption was made that there are 24 working days in a month. This in effect means that the required volume per month is also the required volume for 24 days.

By using this available data, the storage requirements (in amount of pallets) for the chilled warehouse could be calculated as follows:

(Volume (kg) ÷ kg per pallet) x (Days Stock / 24)

= Number of pallets stored per product

As can be seen in Appendix A, the above calculation showed that the facility will need to provide storage space for a total of 5995 pallets. The facility will thus be designed to store a minimum of **6000** pallets.

The company requires that future expansion should be kept in mind at all times. The availability of land is in short supply in the vicinity of the Clayville site.

Another requirement is that every department should be designed in six meter modules. This eases the positioning of columns inside the warehouse and it accommodates aisle widths which facilitates the movement of equipment around the warehouse.

7. Layout design

The layout design of each of the individual departments will result in the design of the facility as a whole. The layout of the storage area, also referred to as the picking area, plays a very important role in the facility since the main function of the warehouse is after all to store the products. Because of this, the layout of the storage area will be given attention first.

7.1 Layout design of storage area

The warehouse can be designed from block stacking (one high) up to six pallets high. It can not be designed to store seven pallets on top of each other within racking, since the necessary warehouse equipment is not capable of reaching such a height for these types of products. The height of the warehouse will not only influence the building cost but also the type of equipment needed as well as the floor space left for future expansion.

If the warehouse is built for four pallets high, floor space will have to be provided for 1500 pallets in order to have storage space for a total of 6000 pallets (1500 x 4). In the case of five and six pallets high provision has to be made for 1200 and 1000 pallets respectively to get to the full amount of 6000.

Please take note that doors have to be at least 2.56m wide and aisles 3.2m where reach trucks will be operating and 3.6m where forklifts will be operating, in order to ensure that these equipment can freely move between aisles and different rooms. Forklifts will only be used in the receiving and loading areas to unload and load delivery trucks since the height of a reach truck makes this task impossible.

Also note that back-to-back racking will be used, meaning that every two rows will be built back to back with each other so that all pallets are only accessible from one side. In effect this means that you can access a specific pallet from one and only one aisle.

The tables below show the cost per square meter for different ceiling heights as well as the costs for different reach trucks, the one type of warehouse equipment that will be needed to move pallets from the receiving area to the storage area and then from the storage area to the dispatching area.

Clover
It's all you need

Warehouse building cost per square meter

Height of ceiling	Cost per square meter
6m ceiling	R 6520
9m ceiling	R 6876
12m ceiling	R 7351

Table 1: Warehouse building cost per square meter

Reach Truck cost differences

Length of Reach truck	Cost
9m	R 500 000
11m	R 650 000

Table 2: Reach Truck cost differences

7.1.1 Building strategy for storage area

The size of a pallet is 1 meter by 1.2 meters. The layout of the storage area and the racking can either be designed for using the 1m side for storing the pallet on to the racks or alternatively it can be designed for using the 1.2m side. In both cases provision has to be made for 0.2m extra space (tolerance) at the back of the pallet, as well as 0.1m on each side of the pallet to accommodate racking uprights and ease of storage. This then implies that for 1m entry the pallet is actually 1.2m (1m + 0.1m + 0.1m) by 1.4m (1.2m + 0.2m). For 1.2m entry the pallet then will be 1.4m by 1.2m. The pictures below illustrate this concept.

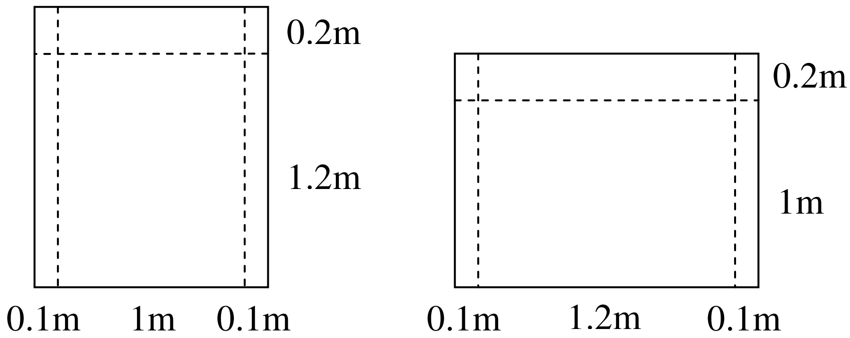


Figure 10: 1m and 1.2 m entry of pallets illustrated

In order to determine the optimal layout of the facility's storage area, many alternatives have to be considered. These alternatives include 1m and 1.2m pallet entry for four, five and six pallets high. An arbitrary area will be used to first determine which building strategy is optimal in terms of the cost per pallet. This chosen optimal strategy will then be used to design layout alternatives in order to find the optimal layout that consumes the smallest area within the specified requirements.

The arbitrary dimensions used are 60m by 60m thus 3600m^2. The diagrams below represent a floor plan for 1m as well as 1.2m entry of pallets for the chosen dimensions. The amount of pallets that will fit on to the floor, within the specified area, when using the two different approaches are calculated below each diagram as well as the total amount of pallets that will be able to fit in to the warehouse when it is built for four, five or six pallets high.

The layouts are only basic layouts to determine the cost per pallet and thus the optimal building strategy. At this point in time it does not show detail such as doors etc.

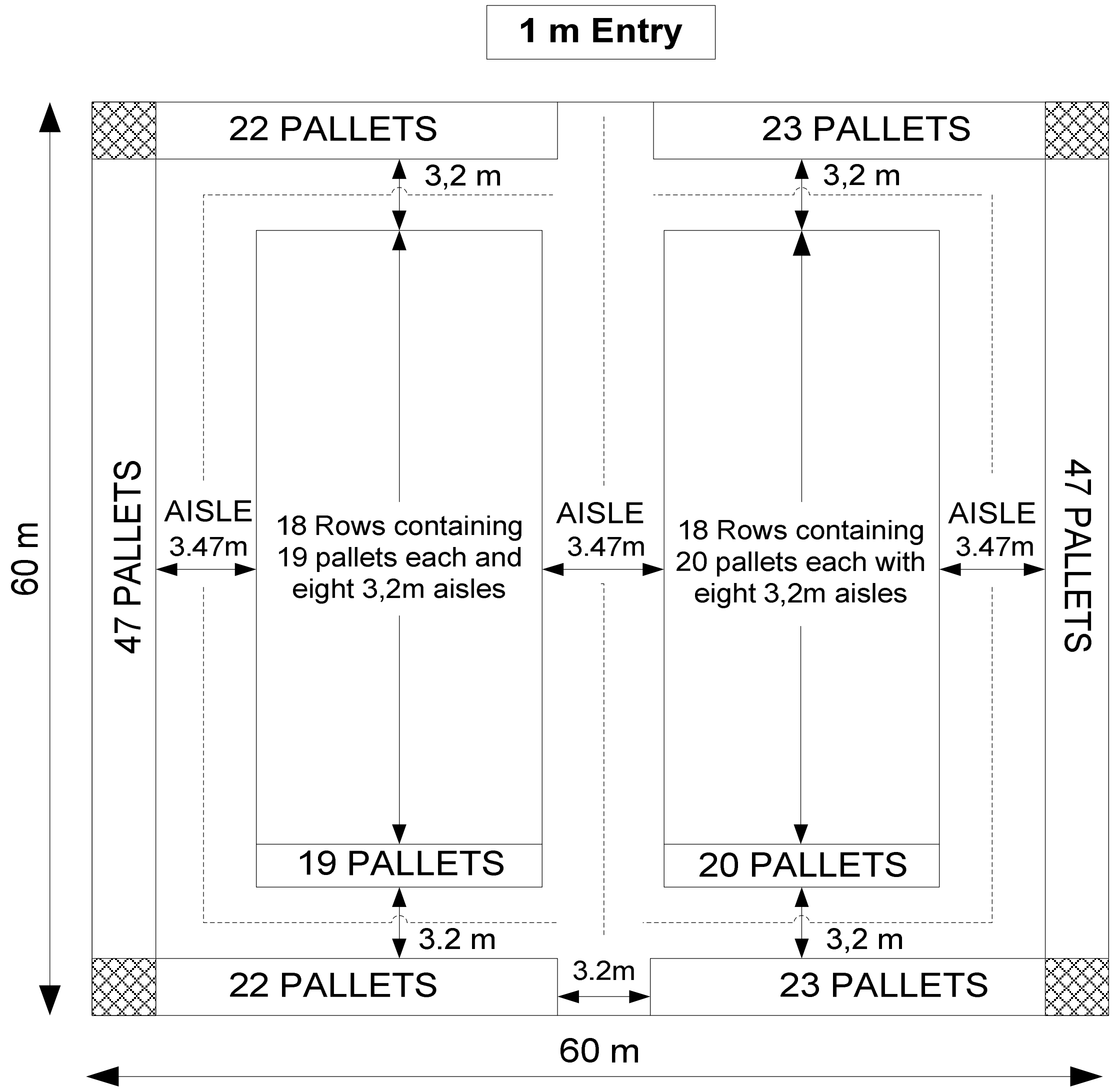


Figure 11: 1m entry of pallets using arbitrary dimensions

The amount of pallets that will fit on to the floor:

22 x 2 = 44

23 x 2 = 46

47 x 2 = 94

19 x 18 = 342

20 x 18 = 360

TOTAL = 886

The total amount of pallets that will fit in to the warehouse when it is built for:

- Four pallets high: 4 x 886 = 3544
- Five pallets high: 5 x 886 = 4330
- Six pallets high: 6 x 866 = 5196

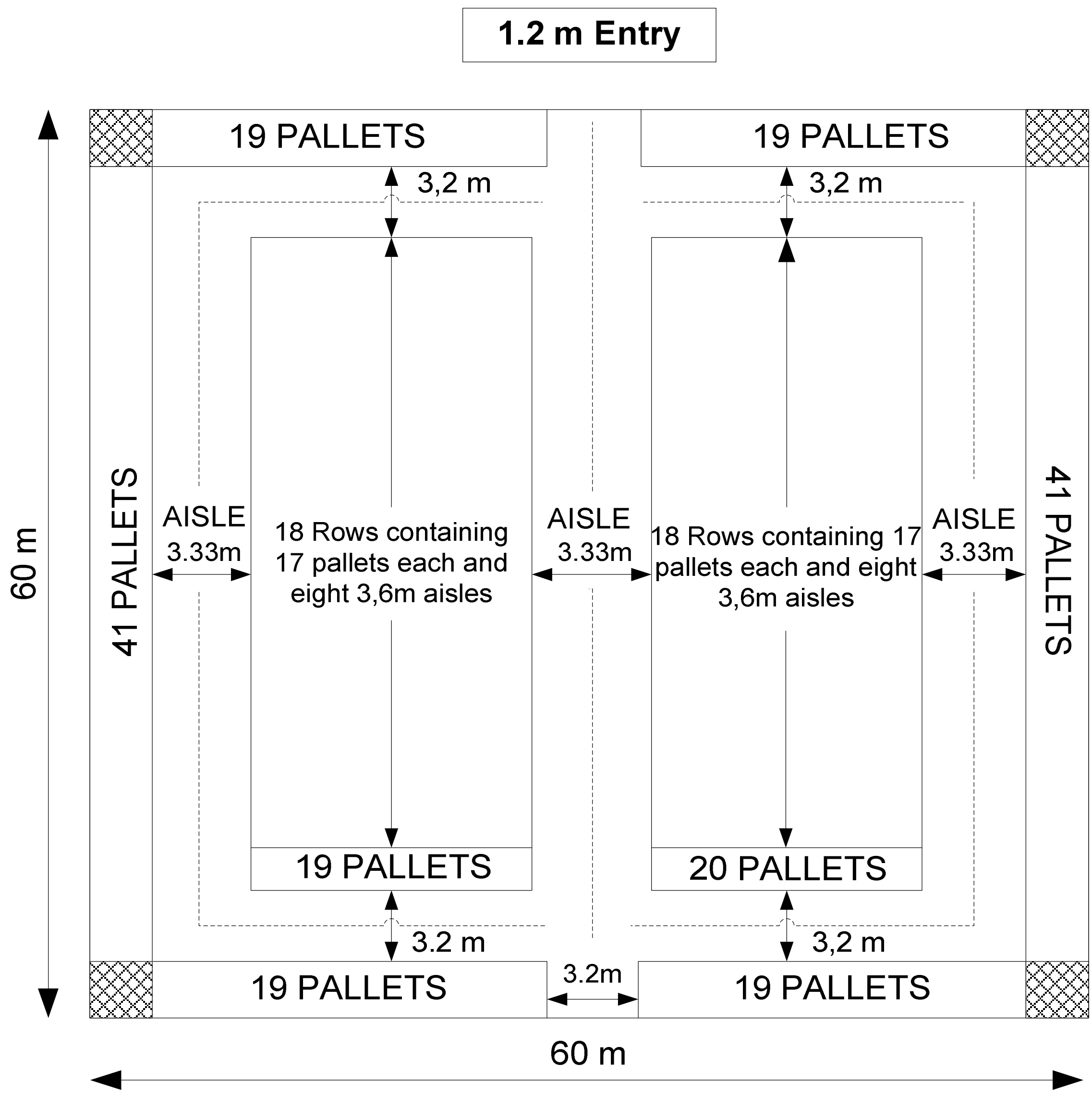


Figure 12: 1.2m entry of pallets using arbitrary dimensions

The amount of pallets that will fit on to the floor:

19 x 4 = 76

41 x 2 = 82

17 x 18 x 2 = 612

TOTAL = 770

The total amount of pallets that will fit in to the warehouse when it is built for:

- Four pallets high: 4 x 770 = 3080
- Five pallets high: 5 x 770 = 3850
- Six pallets high: 6 x 770 = 4620

The table below summarizes the above options and shows the total building cost as well as the associated cost per pallet for each building strategy.

The comparison shows that option five will result in the lowest cost per pallet. This then implies that the best building strategy is 1m entry of pallets and six pallets high.

The cost of warehouse equipment has not yet been taken in to account but will be considered once the warehouse equipment requirements have been determined.

Summary of building strategies and associated cost per pallet

Summary of building strategies and associated cost per pallet

Option	1m or 1.2m entry	No. of pallets high	No. of pallets on floor	Total no. of pallets	Length (m)	Width (m)	Area (m^2)	Applicable building cost (R/m^2)	Total building cost	Cost per pallet
1	1m	4	886	3544	60	60	3600	6520	23472000	6623
2	1.2m	4	770	3080	60	60	3600	6520	23472000	7621
3	1m	5	886	4430	60	60	3600	6876	24753600	5588
4	1.2m	5	770	3850	60	60	3600	6876	24753600	6430
5	**1m**	**6**	**886**	**5316**	**60**	**60**	**3600**	**7351**	**26463600**	**4978**
6	1.2m	6	770	4620	60	60	3600	7351	26463600	5728

Table 3: Summary of building strategies and associated cost per pallet

7.1.2 Alternative layouts for storage area

The optimal building strategy of 1m entry of pallets and six pallets high will now be used to develop layout alternatives. Please note that, as mentioned previously:

- the layout has to be designed in six meter modules,
- the warehouse has to be able to store a minimum of 6000 pallets and
- future expansion has to be taken in to account.

The arbitrary dimensions of 60m by 60m have proven to be able to store a total of 5316 pallets when using 1m entry and six pallets high and thus do not meet the requirement of 6000 pallets. Consider this to be **Alternative 1** for the layout of the storage area. The approach that will be followed when developing the layout alternatives is to add a 6m module to the dimensions of the previous layout until the requirement of 6000 pallets is met.

Alternative 2:

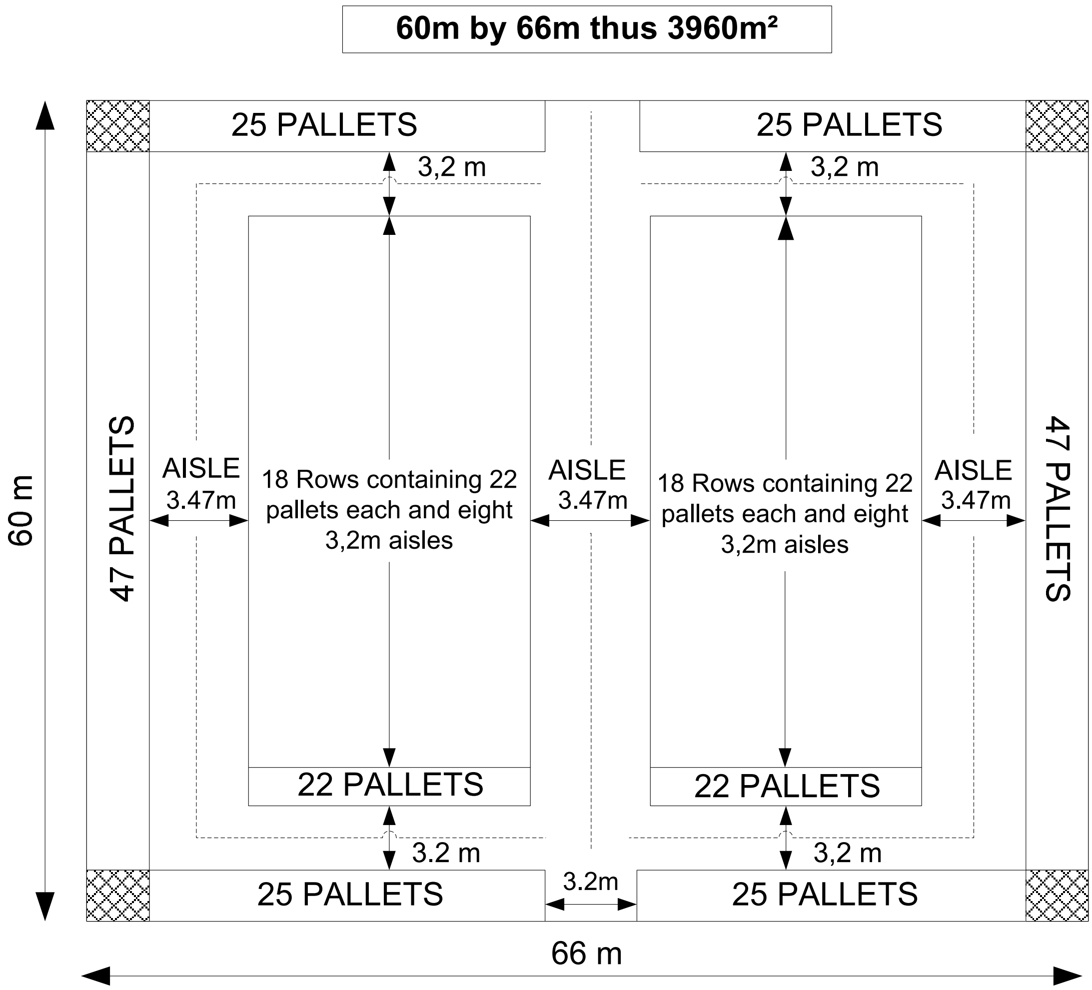


Figure 13: Second alternative for the layout of the storage area

The amount of pallets that will fit on to the floor:

25 x 4 = 100

47 x 2 = 94

22 x 2 x 18 = 792

TOTAL = 986

The total amount of pallets that will fit in to the warehouse is thus 6 x 986 = 5916. This fails to meet the set requirement of 6000 pallets by 1.4% which is quite minimal but is still unacceptable.

Alternative 3:

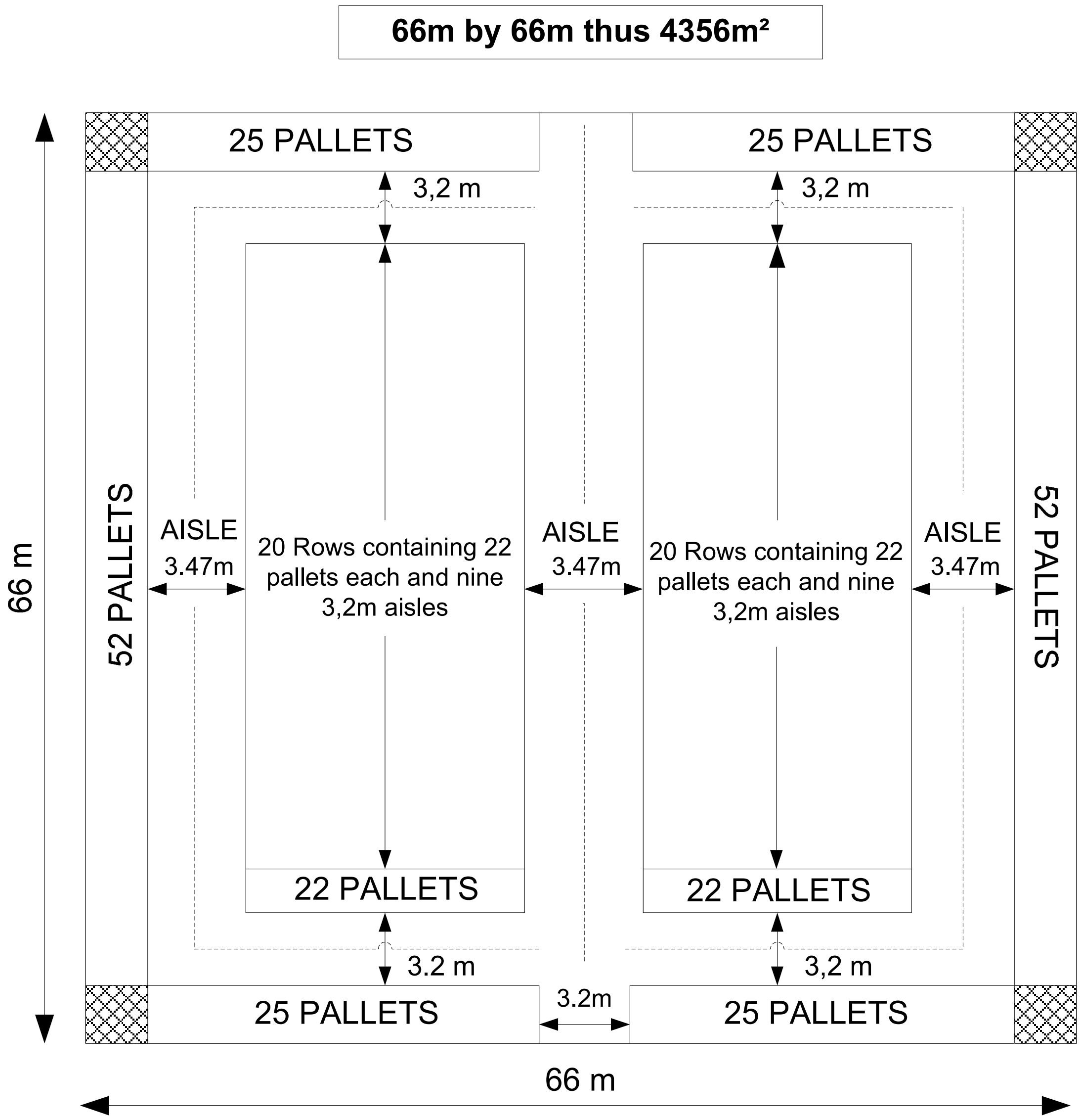


Figure 14: Third alternative for the layout of the storage area

The amount of pallets that will fit on to the floor:

25 x 4 = 100

52 x 2 = 104

22 x 2 x 20 = 880

TOTAL = 1084

The total amount of pallets that will fit in to the warehouse is thus 6 x 1084 = 6504. This exceeds the set requirement of 6000 pallets with 8.4%.

The table below summarizes the three layout alternatives. Even though alternative two has the lowest associated cost per pallet it does not meet the prescribed requirement of 6000 pallets and thus alternative three is seen as the optimal layout for the storage area.

Summary of layout alternatives and associated cost per pallet

Alternative	No. of pallets on floor	Total no. of pallets	Length (m)	Width (m)	Area (m^2)	Applicable building cost (R/m^2)	Total building cost	Cost per pallet
1	886	5316	60	60	3600	7351	26463600	4978
2	986	5916	60	66	3960	7351	29109960	4921
3	**1084**	**6504**	**66**	**66**	**4356**	**7351**	**32020956**	**4923**

Table 4: Summary of layout alternatives and associated cost per pallet

An area of 4356 m^2 will thus be used as the space requirement for the storage area when Muther's systematic layout planning steps are implemented.

7.2 Layout design of receiving area

As mentioned previously, products will be received from the factory on the Clayville site as well as from Clover's other factories. The products that will be received through the wall of the factory in to the warehouse are referred to as internal receiving, while products that are delivered with delivery trucks from other factories around the country are referred to as external receiving.

In order to keep the administration inside the warehouse as simple as possible, it would be more sensible to receive the internal and external products separately. This means that provision would be made for two receiving areas.

7.2.1 Available data relevant to receiving area

Please note that, as mentioned previously, Clover is a fast moving consumer goods company (FMCG) and their products are perishable so they are not able to keep great amounts of inventory, thus only 5995 pallets will be stored in the warehouse.

The amount of pallets that are received and dispatched, thus the throughput of the warehouse will be much higher. The data that summarizes the amount of pallets that will be received internally as well as externally can be seen in Appendix A of this document.

A total of 32304 pallets will be received through the factory wall into the warehouse per month, while 8964 pallets will be received from other facilities.

7.2.1.1 On-site production i.e. internal receiving

The data below is relevant to the internal receiving area that will be designed. Please note that answers to all calculations will be round up or down to the nearest whole number, depending on what is being calculated, in order to work with full pallets etc.

- Products will be received over a period of 16 hours per day.
- The department will be active for 24 days in a month.
- The total number of working hours per month can thus be calculated as follows: 16 hours x 24 days = 384 hours per month.
- 32304 pallets will be received internally per month.
- 32304 pallets per month / 24 days = 1346 pallets per day.
- 32304 pallets per month / 384 hours per month = 84.125 thus 85 pallets per hour.
- It takes 3.5 minutes to receive one pallet, thus 17 pallets (60 / 3.5 = 17.14 thus only 17 pallets effectively) can be received by one person every hour. This means that five people will be needed at the internal receiving area (85 pallets per hour / 17 pallets per person per hour = 5 people).
- Scanners are part of the warehouse equipment that will be needed to scan barcodes to put the new products that are received into the warehouse management system. Since five people will be needed in the internal receiving area, five scanners will be needed as well.
- A reach truck takes 5 minutes to transfer a pallet from the receiving area to the storage area, meaning it can move 12 pallets per hour (60 / 5 = 12).
- Since 85 pallets are received per hour, eight reach trucks will be needed at the internal receiving area (85 pallets per hour / 12 pallets per hour per reach truck = 7.08, thus eight reach trucks).
- There will be assumed that floor space will have to be provided for 45 minutes worth of production of pallets in the receiving area. This means

that if 85 pallets are received per hour, 64 pallets (85 x 45 / 60 = 63.75 thus 64) will be received in 45 minutes. These 64 pallets will take up space in the receiving area while it is being checked and a barcode placed on the products before it is taken to the storage area by a reach truck.

- Please take note that only full pallets of products will be received from the factory through the wall in to the warehouse.

7.2.1.2 Off-site production i.e. external receiving

The data below is relevant to the external receiving area that will be designed.

- Products will be received over a period of 24 hours per day.
- There will be three shifts of eight hours each in the 24 hour period.
- The department will be active for 24 days in a month.
- 8964 pallets will be received externally per month (refer to Appendix A).
- The amount of pallets that will be received in a day can be calculated as follows: 8964 pallets per month / 24 days per month = 373.5 thus 374 pallets per day.
- 50% of the amount of pallets received in a day will be received during the first eight hour shift, thus 50% of 374 pallets results in 187 pallets. This then means that 24 pallets are received per hour during the first shift which is equal to one primary delivery truck per hour. The other 50% will be received during the second and third shift. This in effect means that the first shift creates the constraint for the external receiving department.
- A forklift takes 1.5 minutes to unload a pallet from a primary delivery truck. One forklift can thus unload 40 pallets per hour (60 / 1.5 = 40). One forklift is thus required to offload trucks at external receiving (No scanners is required during offloading).

- It is assumed that 75% of the 24 pallets delivered by a truck will be full pallets i.e. pallets that is fully stacked by one type of product. This results in 18 full pallets (24 x 75 / 100 = 18).
- The other 25% or 6 pallets contain more than one product (an average of three products per pallet) and will need to be separated, by the workers in the receiving area, on to different pallets. This means 36 pallets (18 + 18 pallets) effectively goes in to the warehouse.
- Similar to the internal receiving department, it takes 3.5 minutes to receive one pallet, thus 17 pallets (60 / 3.5 = 17.14, thus only 17 pallets effectively) can be received by one person every hour. This then means that three people will be needed at the external receiving area to receive 36 pallets per hour. If three people are needed at the external receiving area two scanners are needed as well.
- Just as with the internal receiving of products, a reach truck takes 5 minutes to transfer (put away) a pallet from the receiving area to the storage area (storage location), meaning it can move 12 pallets per hour (60 / 5 = 12). Three reach trucks will be required to put away the 36 pallets within an hour. If three reach trucks are needed at the external receiving area then three scanners are needed as well.
- As with the internal receiving of products, floor space will have to be provided in the receiving area for pallets, while it is being checked and a barcode placed on the products before it is taken to the storage area by a reach truck. 36 pallets will be received, by the 3 workers in the receiving area, taking 3.5 minutes per pallet thus (36 x 3.5) / 3 = 42 minutes. Thus the maximum time it takes to offload, receive and store all the pallets on a delivery truck is 36 (1.5 x 24) minutes for offloading + 42 minutes for receiving + 60 (5 x 36 / 3) minutes to put the pallets away = 138 minutes. The put away time of 60 minutes can be reduced if reach trucks becomes available from other areas. The stage area inside will be occupied for this time. To accommodate 8 trucks in 8 hours you require (8 trucks x 138

minutes) / (8 hours x 60 minutes) = 2.3 stage areas thus 3 stage areas that must be able to store 36 pallets each.

- At average it takes around 1.5 hours for a truck to dock, off-load plus handle documentation. This is then the time that a delivery truck actually takes up a parking bay. To accommodate 8 trucks in 8 hours you require (8 trucks x 90 minutes) / (8 hours x 60 minutes) = 1.5 thus 2 docking bays to offload trucks.

7.2.2 Basic space requirements for receiving areas

The steps followed in the systematic layout planning approach by Muther will determine what the layout of all the departments will look like. The diagrams below just demonstrate the space that will be required by the internal and external receiving areas respectively.

Please note that as mentioned previously, forklifts will be used to unload delivery trucks and thus provision has to be made for aisles of 3.6m wide in the receiving areas to accommodate the equipment.

7.2.2.1 Internal receiving area

The internal receiving area will provide floor space for 45 minutes worth of production of pallets, as was already mentioned. This was calculated previously to be 64 pallets. A pallet has the dimensions of 1m by 1.2m and 10cm spaces will be allowed between pallets. The diagram below illustrates that a space of 15.6m by 17.5m will approximately be needed for the internal receiving area. 18m by 18m thus 324m^2 will be used as the space required by the internal receiving area in order to build it in six meter modules.

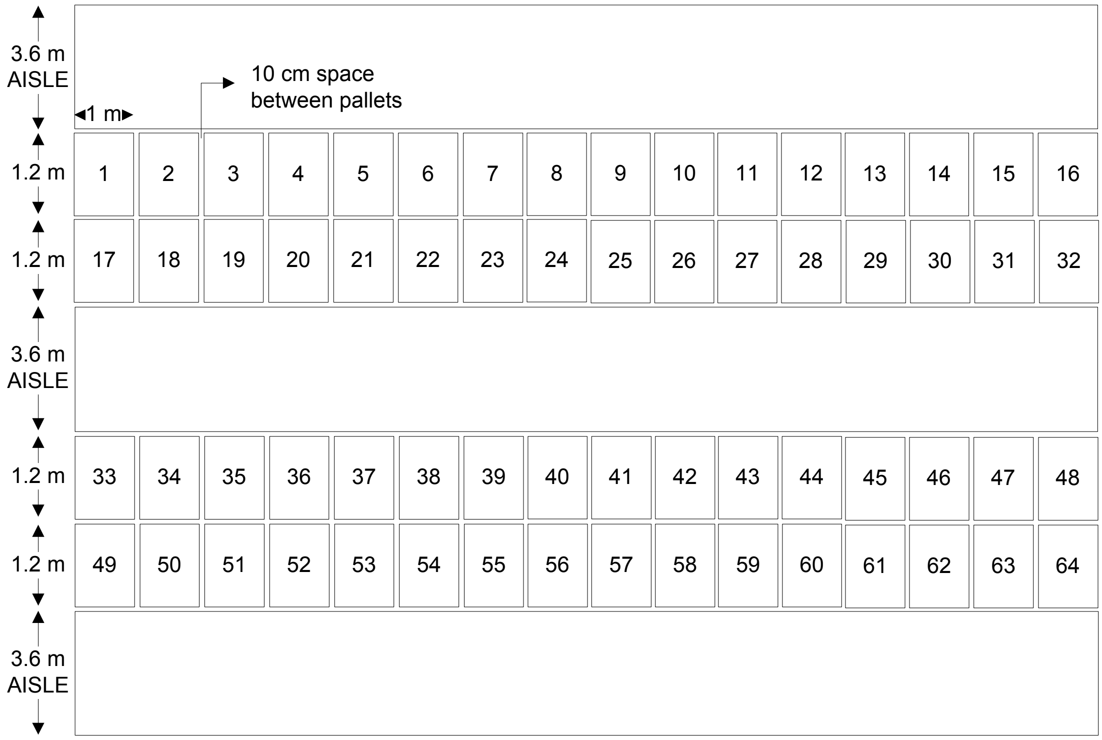


Figure 15: Space required by internal receiving area

7.2.2.2 External receiving area

The external receiving area will have to provide floor space for 108 pallets. The layout will be similar to the internal receiving area in the sense that 10cm spaces will also have to be provided between pallets as well as an aisle of 3.6m wide to gain access to pallets. The diagram below once again gives an idea of what the external receiving area will look like, but it is subject to change when Muther's systematic layout planning steps are implemented.

As illustrated by the diagram below, the approximate space that will be needed for the external receiving area is 18m by 19.7m. This will be round up to 18m by 24m thus 432m² in order to build it in six meter modules. Thus 432m² will be used as the space required by the external receiving area. Please note that the space required by the two parking bays for the external receiving area is not included in the above space requirements. This will be taken in to account though when the layout alternatives are developed.

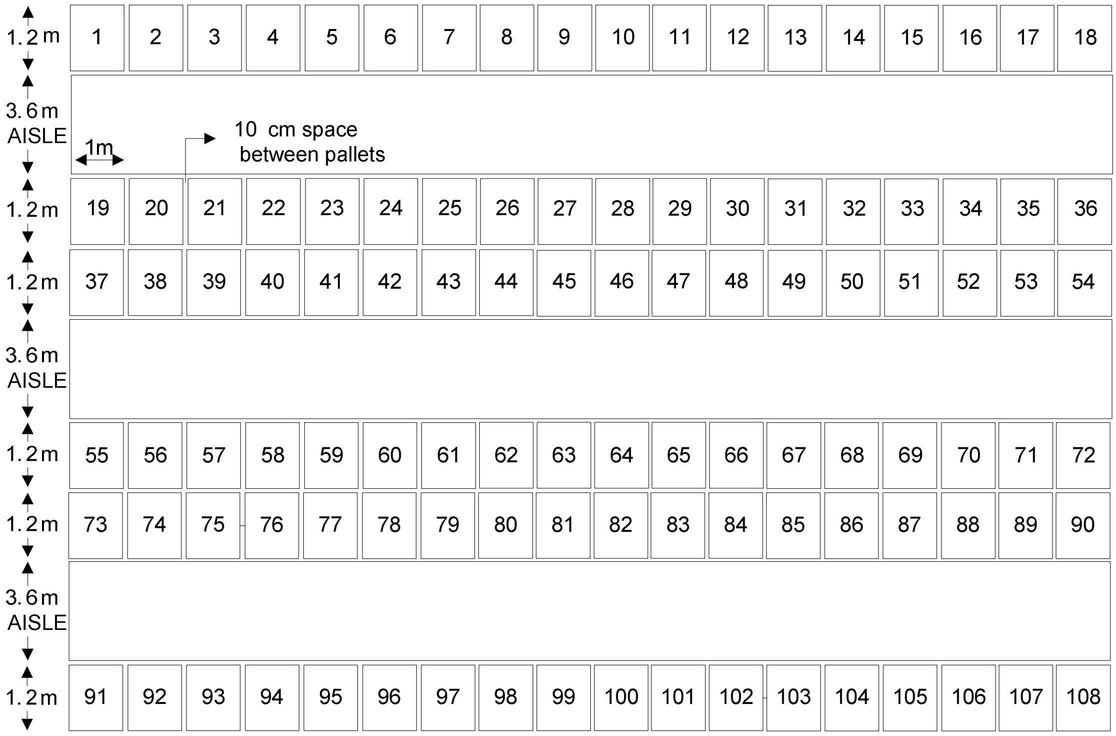


Figure 16: Space required by external receiving area

7.3 Layout design of dispatching area

The dispatching area will consist of:

- Stage areas and
- Dock cubicles.

Please note that the assumption is made that the same amount of pallets that are received per hour should be dispatched per hour to ensure that the contents level of the warehouse remains stable. If more products are received than dispatched, the warehouse might exceed its capacity. On the other hand, if more products are dispatched than received, the capacity of the warehouse will not be optimally utilized.

Products will be dispatched in three eight hour shifts, thus over a 24 hour period and will be divided as follows:

- 40% during the first shift.
- 30% during the second shift.
- 30% during the third shift.

Stage areas are a term that is used to refer to floor space within the warehouse that is allocated to temporarily keep pallets that are ready and waiting to be dispatched to the customer that ordered it. Each stage area contains the products from a separate order to ensure that products from different orders do not get mixed up. An amount of 28 pallets can fit in to one stage area since that is also the amount that can fit in to a truck if required.

It is assumed that 75% of the 24 pallets inventory ordered by a customer, thus 18 pallets, will be full pallets i.e. pallets that is fully stacked by one type of product. The other 25% or 6 pallets contain more than one product. These pallets are stacked with cases of different products that are individually picked by pickers in the storage area. These individual picks of different cases of products are referred to as tasks. A task is just an instruction to a picker to go to a certain location in the storage area and pick a certain amount of cases of a certain product.

Dock cubicles are similar to parking bays referred to in the external receiving area. It is basically only an opening in the wall off the warehouse where goods can be loaded on to a truck. A dock cubicle is the same width as a truck, which is 2.8m. A dock leveler is used to ease the movement of the forklifts transporting the products from the warehouse in to the back of the truck.

Sufficient space has to be provided on the outside of the warehouse, in front of the dock cubicles for multiple trucks to gain access to the different dock cubicles. Provision is thus made for only one dock cubicle within a 6m module.

The length of a truck is usually 18m which makes it difficult to reverse these vehicles in order to park it with the back of the truck facing the dock cubicle. 50m will thus be provided for maneuvering trucks in and out of dock cubicles.

All the products that have been ordered by a certain customer (irrespective of whether it is a full pallet of products or different cases of products stacked on to one pallet) will already be stacked on pallets and be waiting in the stage area by the time the truck arrives to collect the order. This means that the time it takes to pick full pallets and tasks have no influence on the time a truck takes up a dock cubicle. The only time that has to be taken in to account is the time it takes a forklift to load a truck.

As mentioned with the external receiving area, it takes a forklift 1.5 minutes to load a pallet on to a truck and a truck usually have to be loaded with 28 pallets meaning that it takes 1.5 x 28 pallets = 42 minutes to load a truck.

7.3.1 Basic space requirements for dispatching area

As mentioned previously, the same amount of pallets that are received per hour has to be dispatched per hour in order to keep the contents level of the warehouse stable.

The following information will be used to determine the space requirements of the stage areas and dock cubicles:

- 1346 pallets are received internally per day.
- 374 pallets are received externally per day.
- Trucks are loaded during three eight hour shifts, thus over a 24 hour period.
- 28 physical pallets (24 pallets inventory) are loaded on to each truck
- A total of 1720 pallets are received per day and need to be dispatched over a 24 hour period.
- 1720 pallets per day / 24 pallets per truck = 71.67 thus 72 trucks are dispatched per day.

7.3.1.1 Basic space requirements for stage area

There will be assumed that stage areas will have to be provided for the pallets of 35% of the trucks that are loaded in the first shift. 40% of the total number of trucks that are loaded in a day will be loaded during the first shift, thus 40% of 72 trucks gives 28.8, thus 29 trucks. 35% of 29 trucks are 10.15. Provision will thus be made for 10 stage areas.

The space requirement for one stage area is the space consumed by 28 pallets. Although trucks usually contain only 24 pallets when it arrives at the external receiving area, 28 pallets can be loaded on to a truck at the dispatching area. The stage areas will thus have to be able to accommodate 28 pallets.

A pallet has the dimensions of 1m by 1.2m and 10cm spaces will be allowed between pallets. The stage area will be designed for two rows of 14 pallets each back-to-back. Provision has to be made for aisles of 3.6m between stage areas in order for checkers to gain access to pallets and for forklifts to access the different stage areas and load different trucks simultaneously.

The diagram on the following page illustrates one stage area.

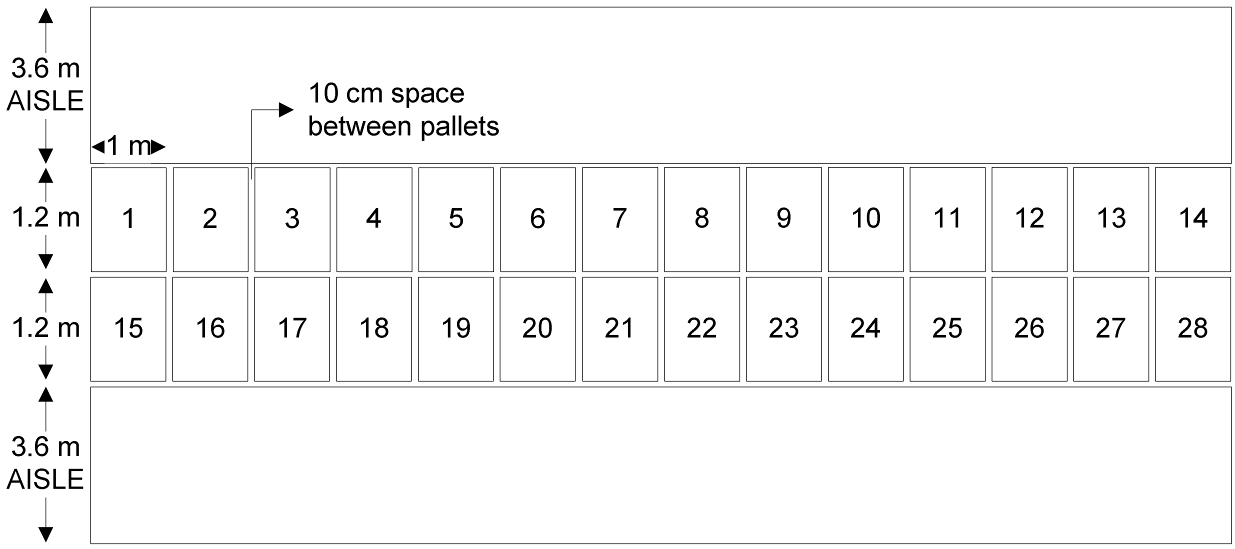


Figure 17: Space required by one stage area

The total length of all the stage areas will thus be (2.4m x 10) + (11 aisles x 3.6m) = 63.6m and the width will be 15.3m. This will be round up to 66m by 18m to build the stage areas in 6m modules. These dimensions will be used as the space requirement for the stage areas which gives a total area of 1188m^2.

7.3.1.2 Basic space requirements for dock cubicles

72 trucks will be loaded per day and on average a truck will take up a dock cubicle for 1.5 hours (similar to the external receiving area). This means that one dock cubicle can accommodate 5 trucks in an eight hour shift (8 hours / 1.5 hours per truck = 5.33 thus only five trucks). 29 trucks will have to be loaded during the first shift (40% of the total of 72 trucks per day), thus six dock cubicles will be needed

As mentioned previously, provision will be made for only one dock cubicle within a 6m module to allow adequate space between trucks. Also mentioned previously is that 50m space has to be provided on the outside for maneuvering trucks in and out of dock cubicles.

The space requirement for the dock cubicles is thus 36m (6 x 6m modules) by 50m thus $1800m^2$.

7.4 Layout design of offices

Provision has to be made for two operational offices, one for personnel working in the receiving department and the other for personnel from the dispatching department. The dispatching department will have more operational workers than the receiving department and will consequently need a larger office that can accommodate more office equipment.

7.4.1 Basic space requirements for offices

The space requirements that will be used for the receiving and dispatching offices respectively are:

- 6m x 3m, thus $18m^2$ and
- 6m x 6m, thus $36m^2$.
- TOTAL: $18m^2 + 36m^2 = 54m^2$

7.5 Layout design of battery room

The details of the battery room are not included in the project scope, but a space requirement has to be determined in order to design the layout of the facility. The battery room is a room in which the batteries of all equipment are charged. The space required by this department is thus dependant on the equipment requirements of the facility.

7.5.1 Equipment requirements

As calculated previously, the internal and external receiving area will respectively require five and two scanners and seven and two reach trucks. The external receiving area will also need one forklift with which to unload the delivery trucks.

The following information is relevant to calculate the equipment requirements for the dispatching area:

- It takes a reach truck five minutes to fetch a pallet of products from the storage area and also five minutes to do a replenishment. (A replenishment is when a reach truck takes products from the bulk storage area and moves it to the pick face area where separate crates of products can be picked).
- It takes a power pallet truck 2 minutes to pick one task. In other words this means that it takes 2 minutes to go to a certain location in the storage area and pick a certain amount of cases of a certain product.
- A maximum of 2000 tasks will be picked per day.
- 72 trucks will be loaded per day.
- 18 of the 24 pallets inventory on a truck will be full pallets, thus a reach truck will have to fetch 18 pallets x 72 trucks = 1296 pallets per day.
- The 6 remaining pallets out of the total of 24 pallets inventory will be stacked with products picked in different tasks. A reach truck is required to bring products from the bulk storage area into the pick face area (replenishment) for these 6 pallets. The replenishments that need to be done per day is 6 pallets x 72 trucks = 432 pallets.
- Products will be picked in two eight hour shifts, 50% during each shift.
- Trucks will be loaded during three eight hour shifts, 40% during the first and 30% in both the second and third shifts. This means that the first shift will constrain the system.

- Reach trucks will need to pick 50% of the 18 full pallets for 72 trucks in an eight hour shift, thus 0.5 x 18 x 72 = 648 pallets in eight hours. A reach truck can pick 96 pallets in an eight hour shift (8 hours x 60 minutes / 5minutes per pallet = 96 pallets). This means that 648 pallets / 96 pallets per reach truck = 6.75 reach trucks. Reach trucks will also need to do the replenishment of 50% of inventory (6 pallets per truck) during the first eight hour shift, thus 0.5 x 6 x 72 = 216 pallets in eight hours. This means that 216 pallets / 96 pallets per reach truck = 2.25. Thus, a total of 9 reach trucks are required for dispatching to take place.
- Power pallet trucks will need to pick 40% of 2000 tasks in an eight hour shift, thus 800 tasks. A power pallet truck can pick 240 tasks in an eight hour shift (8 hours x 60 minutes / 2 minutes per task = 240 tasks). This means that 800 / 240 = 3.33 thus 4 power pallet trucks will be needed. A picker requires a scanner for each power pallet truck thus 4 scanners are required.
- Forklifts will need to load 28 pallets (irrespective of whether it is full pallets of products or different cases of products stacked on to one pallet) per truck for 29 trucks in the first eight hour shift, thus 28 x 29 = 812 pallets. A forklift can load 320 pallets in an eight hour shift (8 hours x 60 minutes / 1.5 minutes per pallet = 320), meaning that three forklifts will be required. No scanners are required for loading.

The table below summarizes the warehouse equipment requirements:

Department	Scanners	Reach trucks	Forklifts	Power pallet trucks
Internal receiving area	13	8	0	0
External receiving area	6	3	1	0
Dispatching area	13	9	3	4
TOTAL:	**32**	**20**	**4**	**4**

Table 5: Summary of equipment requirements

All reach truck drivers require scanners to scan the barcode of products when they are taking pallets of products to the storage area or fetching it from the storage area. This is done in order to ensure that the reach truck is indeed at the correct location for certain products.

The total of thirteen scanners required by the internal receiving area is thus made up of five scanners for checkers and eight for the reach trucks. The external receiving area requires three scanners for checkers as well as three for the reach trucks. The checkers at the dispatching area do not require scanners since they only compare the pallets in a stage area with the customer's order (load sheet) to ensure that it corresponds with one another. The reach trucks required for dispatching and replenishment requires a total of nine scanners.

The batteries of the reach trucks, forklifts and power pallet trucks will be charged in the battery room. The batteries of the scanners are quite small and can easily be charged and changed when needed. The battery room is usually 6m wide. A crane moves up and down the middle of the battery room and can access batteries on either side of it. Each machine has three batteries. The one is used in the machine, one is cooling down after being used before it can be charged again and the other one is being charged.

Space required by the batteries of the different types of equipment is as follows:

- 2m per reach truck.
- 1.5m per forklift.
- 1.2m per power pallet truck.

Provision has to be made for a docking area where the equipment can enter the battery room and the crane can access the equipment in order to remove or replace the battery. Provision will be made for a 6m by 6m docking area.

The battery room should also include a maintenance area for the equipment. Provision will be made for a maintenance area of 10m by 6m.

The diagram below illustrates on a high level what the battery room will look like and the space that it will consume. Please note that 30cm spaces (not shown on the diagram below) will be allowed between each station.

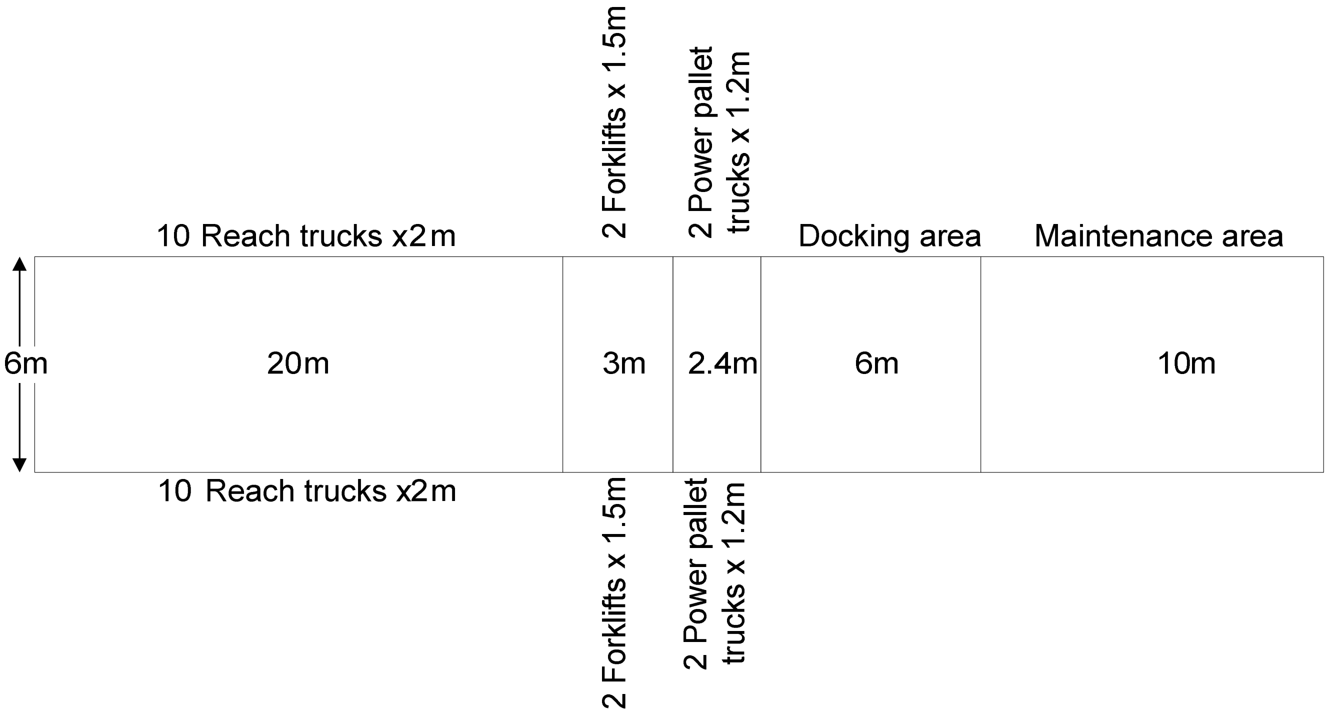


Figure 18: Space required by battery room

The total space required by the battery room, which include the 14 stations on each side of the crane and the docking area and maintenance area is thus: 20m + 3m + 2.4m + (14 x 30cm) + 6m + 10m = 45.6m by 6m. This will be round up to 48m by 6m in order to build the battery room in 6m modules. The total area required by the battery room is thus 48m by 6m, thus 288m².

7.5.1.1 Verification of building strategy for storage area

When the building strategy for the storage area had been determined, the cost of warehouse equipment had not yet been taken in to account. Since the warehouse equipment requirements have now been determined, the building strategy for the storage area can be verified to ensure that it is indeed the best strategy when all applicable costs are taken in to consideration.

Option	1m or 1.2m entry	No. of pallets high	Total no. of pallets	Applicable reach truck cost	Total reach truck cost	Applicable building cost (R/m²)	Total building cost	Cost per pallet
1	1m	4	3544	500 000	10000000	6520	23472000	9445
2	1.2m	4	3080	500 000	10000000	6520	23472000	10868
3	1m	5	4430	500 000	10000000	6876	24753600	7845
4	1.2m	5	3850	500 000	10000000	6876	24753600	9027
5	**1m**	**6**	**5316**	**650 000**	**13000000**	**7351**	**26463600**	**7424**
6	1.2m	6	4620	650 000	13000000	7351	26463600	8542

Table 6: Verification of building strategy for storage area

The table above confirms that option five remains the best building strategy for the storage area when all applicable costs are included. Costs that remain the same for all options such as the cost of the scanners, forklifts and power pallets trucks are not considered in the table above, since these costs do not vary for the different options and thus does not influence the choice of building strategy.

7.5.2 Personnel requirements

As mentioned previously, the equipment requirements have an influence on the personnel requirements since each forklift, reach truck and power pallet truck will need a driver. The fact that the warehouse will be operating in shifts, also influences the personnel requirements. Since the equipment requirements have now been determined, the personnel requirements can also be determined.

The internal receiving area will be operative for two shifts and 50% of a day's pallets will be received during each shift, meaning that a total of ten checkers and sixteen reach truck drivers will be required.

The external receiving area will be operative for three shifts. 50% of the day's pallets will be received during the first shift while the other 50% will be received over the second and third shifts. The first shift, which is the busiest shift, requires three checkers, three reach truck drivers and one forklift driver. There can not be assumed that the 50% of pallets received over the second and third shifts are divided equally into 25% per shift. For this reason provision will be made for two checkers, two reach truck drivers and one forklift driver for the second and third shifts respectively. The total personnel requirements for the external receiving area is thus seven checkers, seven reach truck drivers and three forklift drivers.

The dispatching of products also takes place over three shifts. 40%, 30% and 30% of a day's pallets will be dispatched over the first, second and third shifts respectively.

It takes a checker 3.5 minutes to check a pallet. This means that one person can check 137 pallets in an eight hour shift (8 hours x 60 minutes / 3.5 minutes per pallet = 137.14 thus 137 pallets). 700 pallets will be received during the first shift which represents 40% of the total amount of pallets received per day. 30% of the total amount of pallets received per day will thus be 525 pallets. This means that six checkers will be needed for the first shift (700 pallets / 137 pallets per person = 5.1, thus six) and 4 checkers for the second and third shifts respectively (525 pallets / 137 pallets per person = 3.8 thus four).

The first shift requires nine reach truck drivers, three forklift drivers and four power pallet truck drivers. In relation to this, the second and third shifts will require seven reach truck drivers [(9 reach trucks / 40%) x 30%], three forklift drivers [(3 forklifts / 40%) x 30%] and three power pallet truck drivers respectively [(4 power pallet trucks / 40%) x 30%].

The total amount of forklift, reach truck and power pallet truck drivers are summarized in the table below as well as the amount of checkers and required.

Job description	Internal Receiving	External Receiving	Dispatching	Total
Forklift driver	0	3	9	**12**
Reach truck driver	16	7	23	**46**
Power pallet truck driver	0	0	10	**10**
Checker	10	7	14	**31**
Supervisor	N/A	N/A	N/A	**8**

Table 7: Summary of personnel requirements

Approximately eight supervisors will be required to manage operations. Offices will be built to accommodate the supervisors.

7.5.3 Warehouse management system equipment requirements

As mentioned previously, the warehouse management system equipment includes the scanners, that tell the above equipment drivers and other warehouse staff what to do, as well as the computers needed to manage the warehouse.

The amount of scanners required has been calculated to be 32. The computer requirements depend on the amount of people that will have access to the warehouse's operational information, which will be determined by the company at a later stage. A computer that will be used as the main "server" of the warehouse will definitely be required.

7.6 Layout design of plant room

The plant room is a room where compressors are stored that are responsible for keeping the chilled warehouse at a certain temperature.

The size required by the plant room is determined by the chilling requirements and thus the size of the warehouse. The relationship between the size of the plant room and the size of the warehouse that is often used is 1:60. The table below summarizes the space requirements of the departments within the warehouse that will require chilling:

Department	**Area required (m^2)**
Internal receiving area	324
External receiving area	432
Storage area	4356
Stage areas	1188
TOTAL:	**6300**

Table 8: Space requirements for chilled departments

The total size of the warehouse that will require chilling is thus 6300m^2, which if it is divided by 60 gives 105m^2. The space requirement for the plant room is thus 105m^2. The length and width of the plant room is not really relevant, as long as a total area of 105m^2 is provided for.

8. Facility planning procedure: Design and Problem Solving

The systematic layout planning steps that was developed by Muther can now systematically be executed since an understanding have been reached of the input data and space requirements have been determined for all departments.

8.1 Measuring Flow

According to Tompkins (Tompkins et al, 2003), the flow among departments is one of the most important factors in the arrangement of departments within the facility. The establishment of a measure of flow is critical to evaluate alternative arrangements of the facility.

A measure of flow can be specified in either a quantitative manner or a qualitative manner. Quantitative measures may include the number of products that moves between the departments per hour or per day. Qualitative measures are used to measure intangible factors such as communication or information. It is measured in terms of a "value" ranging from being absolutely necessary for departments to be next to each other to it being undesirable for departments to be close to each other.

8.1.1 Quantitative Flow Measurement

As mentioned previously, flows may be measured quantitatively in terms of the amount moved between departments. According to Muther's SLP approach, a "From-To chart" will be used to record these flows.

According to Tompkins (Tompkins et al, 2003), a "From-To chart" is constructed as follows:

1. List all departments of the warehouse down the row and across the column following the overall flow pattern.

   The operational offices, battery room and plant room are lastly listed since products do not physically move to these departments thus it is not part of the flow pattern, but they are necessary for the facility to function as a whole.

2. Establish a measure of flow for the facility that accurately indicates equivalent flow volumes. If the items moved are equivalent with respect to ease of movement, the number of trips may be recorded in the "From-To chart".

   The number of times a reach truck or forklift moves between departments per day have been identified as the measure of flow for constructing the "From-To chart" below.

FROM \ TO	Internal Receiving area	External Receiving area	Storage area	Stage areas	Dock cubicles	Offices	Battery room	Plant room
Internal Receiving area		0	1346	0	0	0	0	0
External Receiving area	0		374	0	0	0	0	0
Storage area	1346	374		1720	0	0	0	0
Stage areas	0	0	1720		1720	0	0	0
Dock cubicles	0	0	0	1720		0	0	0
Offices	0	0	0	0	0		0	0
Battery room	0	0	0	0	0	0		0
Plant room	0	0	0	0	0	0	0	

Table 9: From-To chart: Quantitative Flow Measurement

8.1.2 Qualitative Flow Measurement

According to Tompkins (Tompkins et al, 2003), flows may be measured qualitatively using the closeness relationships values developed by Muther and given in table 6. The values may be recorded in conjunction with the reasons for the closeness value using the “relationship chart”.

Value	Closeness
A	Absolutely necessary
E	Especially important
I	Important
O	Ordinary closeness OK
U	Unimportant
X	Not desirable

Table 10: Closeness rating

A “relationship chart” may be constructed as follows (Tompkins et al, 2003):

1. List all departments on the relationship chart.
2. Conduct interviews or surveys with persons from each department listed on the relationship chart and with the management responsible for all departments.
3. Define the criteria for assigning closeness relationships and itemize and record the criteria as the reasons for relationship values on the relationship chart. The codes and reasons for the relationship values can be seen below in table 7.

Code	Reason
1	Personnel requirements
2	Flow of products
3	Communication
4	Inventory control
5	Administration
6	Chilling requirements

Table 11: Reasons behind the "Closeness" value

4. Establish the relationship value and the reason for the value for all pairs of departments.

   This concept is explained in the diagram below:

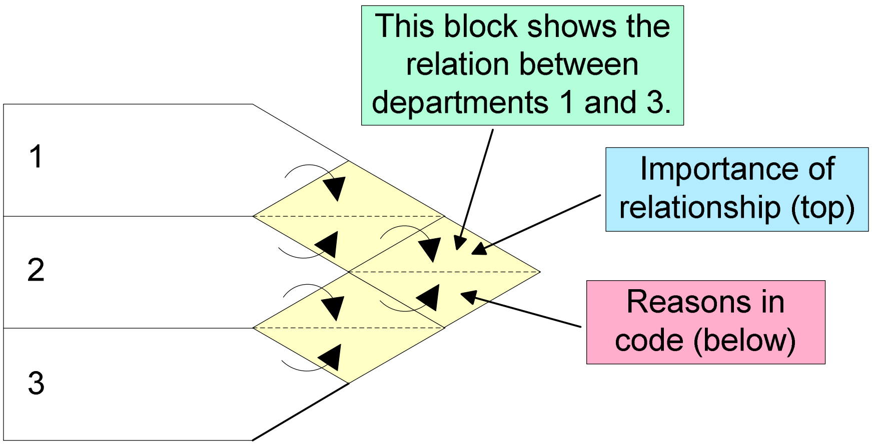


Figure 19: Explanation of the Activity Relationship Chart

5. Allow everyone having input to the development of the relationship chart an opportunity to evaluate and discuss changes in the chart.

The activity relationship chart for the warehouse can be seen on the following page.

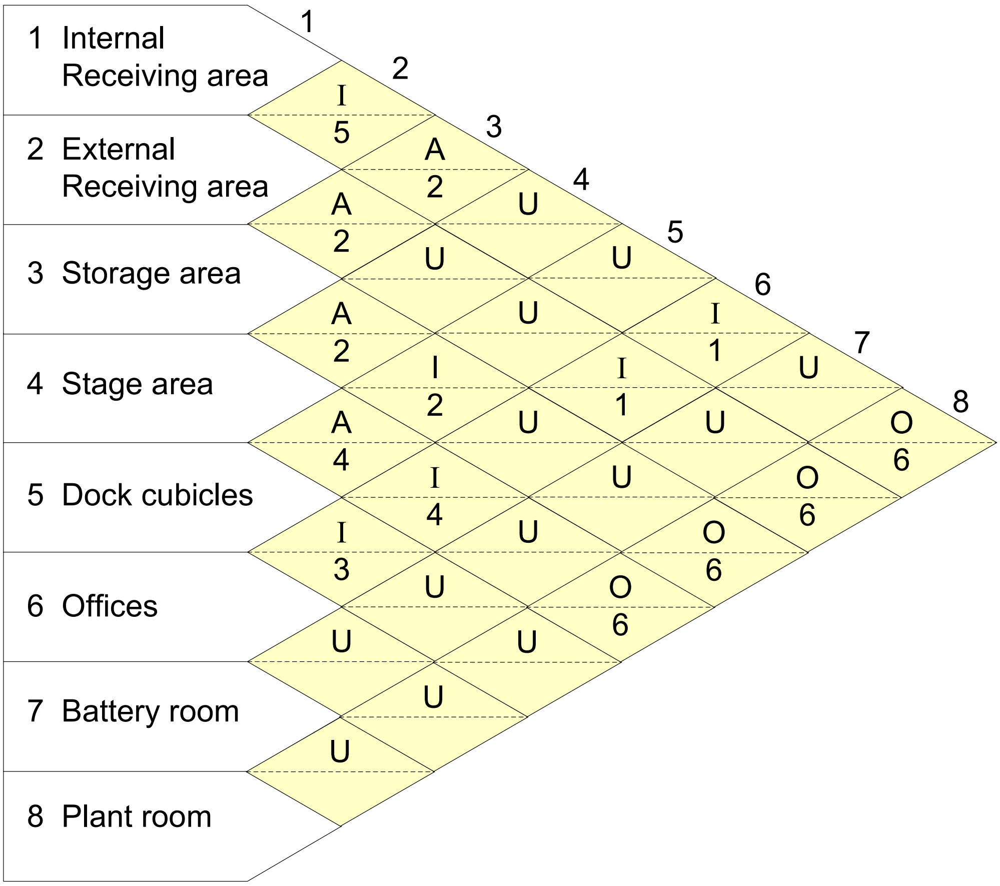


Figure 20: Activity Relationship Chart – Qualitative Flow Measurement

Up to step three of Muther's SLP approach have now been completed (refer to page 13 of this document).

8.2 Space requirements

Step four of Muther's SLP approach is to determine space requirements for all the departments. This has already been determined when the input data and activities have been analyzed. The table below summarizes the space required by each department as determined previously:

Department	Length (m)	Width (m)	Area Required (m^2)
Internal Receiving area	18	18	324
External Receiving area	18	24	432
Storage area	66	66	4356
Stage area	66	18	1188
Dock cubicles	36	50	1800
Offices: Receiving Dispatching	6 6	3 6	18 36
Battery room	48	6	288
Plant room	N/A	N/A	105
TOTAL:			8547

Table 12: Space requirements for different departments

Please note that although the dock cubicles form part of the departments necessary for the warehouse to function as a whole, it is not a part of the warehouse building as such. In other words, the 1800m^2 required by the dock cubicles is an area *outside* the warehouse where trucks will park when they are collecting an order. This 1800m^2 are then deducted from the total of 8547m^2 to get to an actual total of **6747m^2**.

8.3 Space available

The diagram below illustrates the open piece of land that is available to build the warehouse. Please remember that the company requires that future expansion should be taken in to account at all times, meaning that the less space the warehouse takes up, the more space will be left for future expansion.

The total area that is available to build the warehouse is approximately 18500m². This includes the space where roads should be built to allow flow around the whole Clayville site.

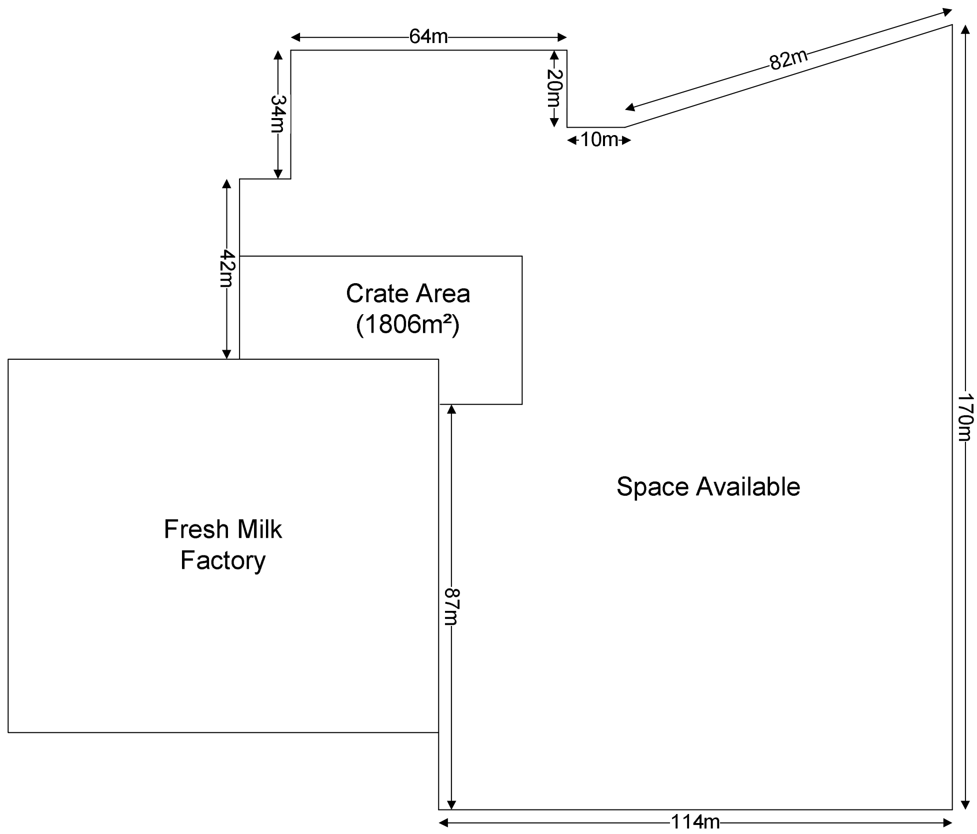
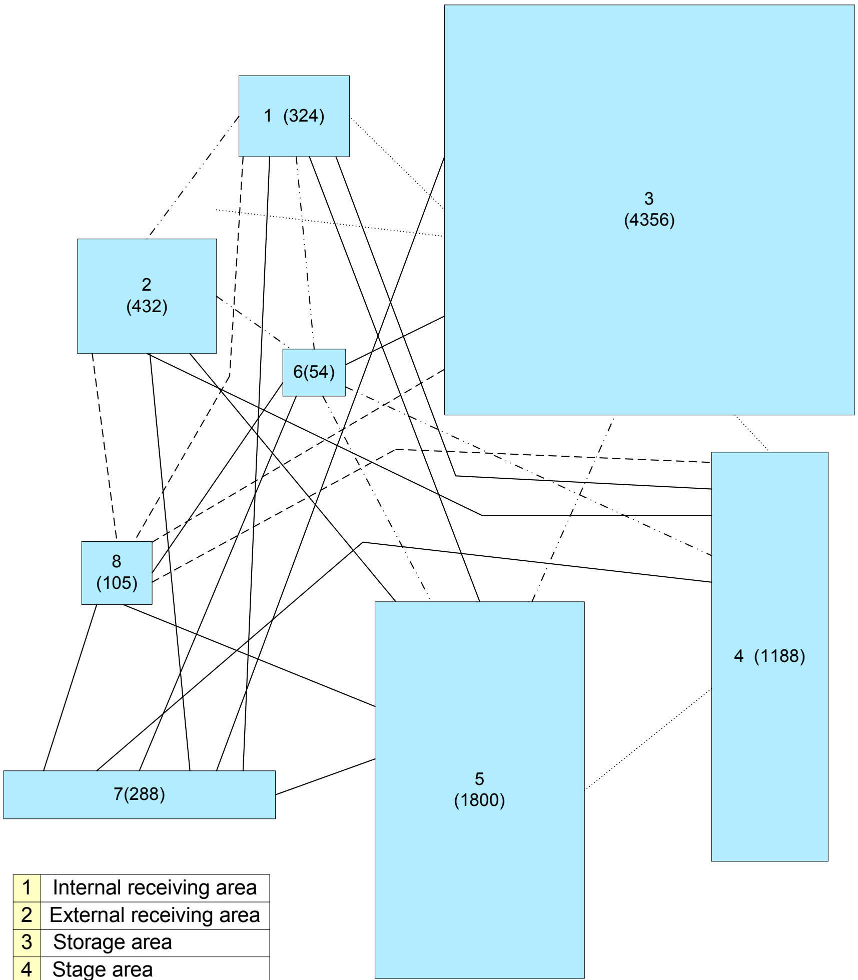


Figure 21: Space available to build warehouse

8.4 Space relationship diagram

The analysis phase of Muther's systematic layout planning procedure has now been completed. There is now being moved on to the "search" phase which starts with step six in the SLP approach, which is the space relationship diagram. The space relationship diagram shows the relationship between departments in terms of the closeness rating specified in the activity relationship chart as well as the space required by each department.

Value	Closeness	
A	Absolutely necessary	
E	Especially important	
I	Important	
O	Ordinary closeness OK	
U	Unimportant	
X	Not desirable	



1	Internal receiving area
2	External receiving area
3	Storage area
4	Stage area
5	Dock cubicles
6	Offices
7	Battery room
8	Plant room

Figure 22: Space Relationship Diagram

8.5 Develop Layout Alternatives

The final step in Muther's SLP approach is to develop layout alternatives for the facility. This can be done using very complex software and algorithms or it can be done by using the From-To chart and the Activity Relationship chart that depicts the relationships between the departments as well as the amount of times equipment moves between departments.

Three alternative layouts will be developed to ensure that a variety of options are taken in to account before deciding on a layout best suited for the warehouse.

The three layout alternatives that were designed can be seen on the following three pages.

Please take note that the shaded areas are not part of the building itself. As mentioned previously, the space required by the dock cubicles is an area *outside* the warehouse where trucks will park when they are collecting an order. The same goes for the parking bays where external receiving takes place, where trucks will park when they are delivering an order.

Space is provided for a road on all sides of the Clayville site, in order to ensure that vehicles can gain access to all areas where required. Please note that the flow of traffic differs for the different layouts. The reason for this is to ease the parking of the delivery trucks since a truck is 18m in length and it is quite difficult to park.

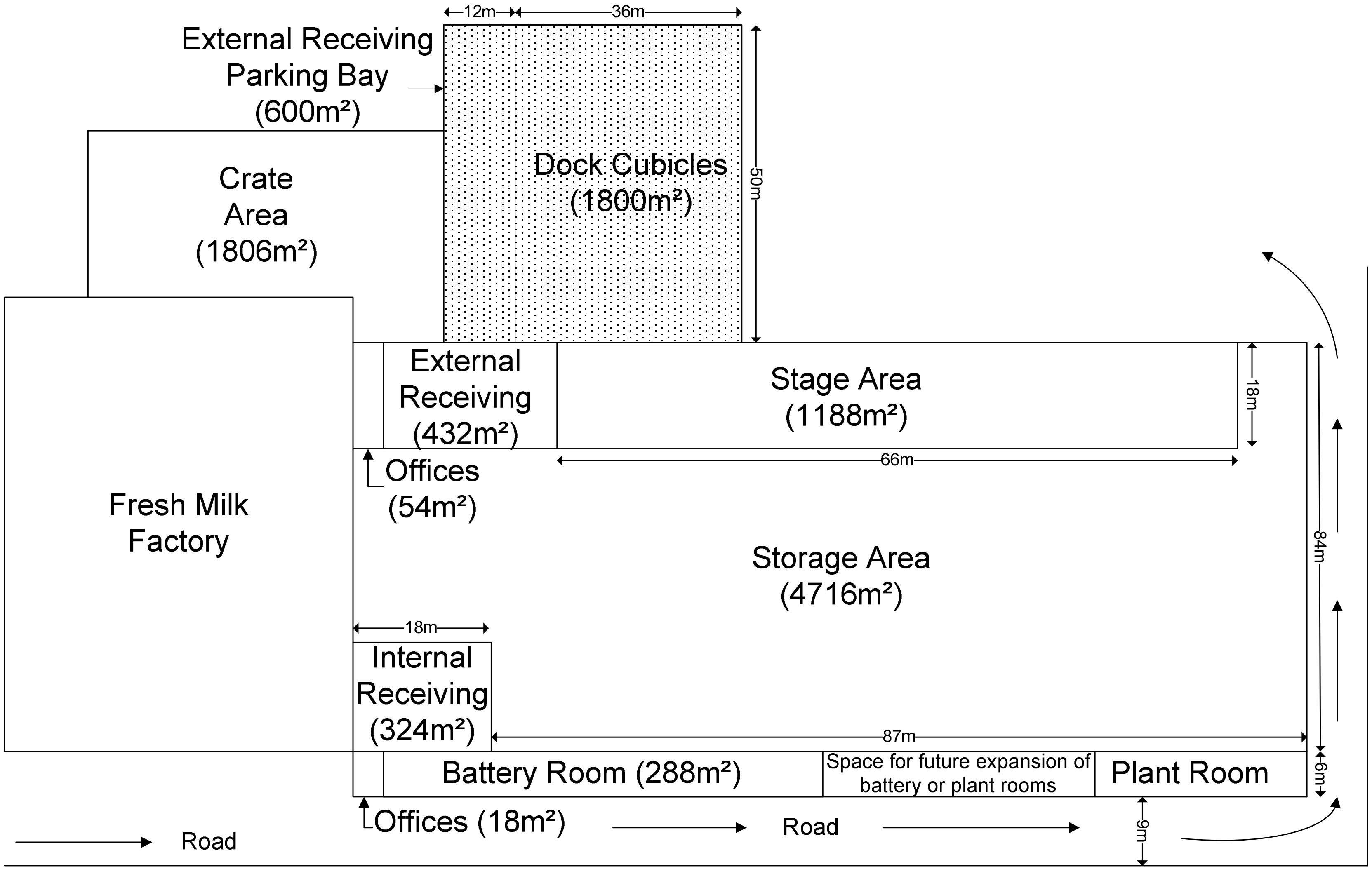


Figure 23: Layout alternative 1

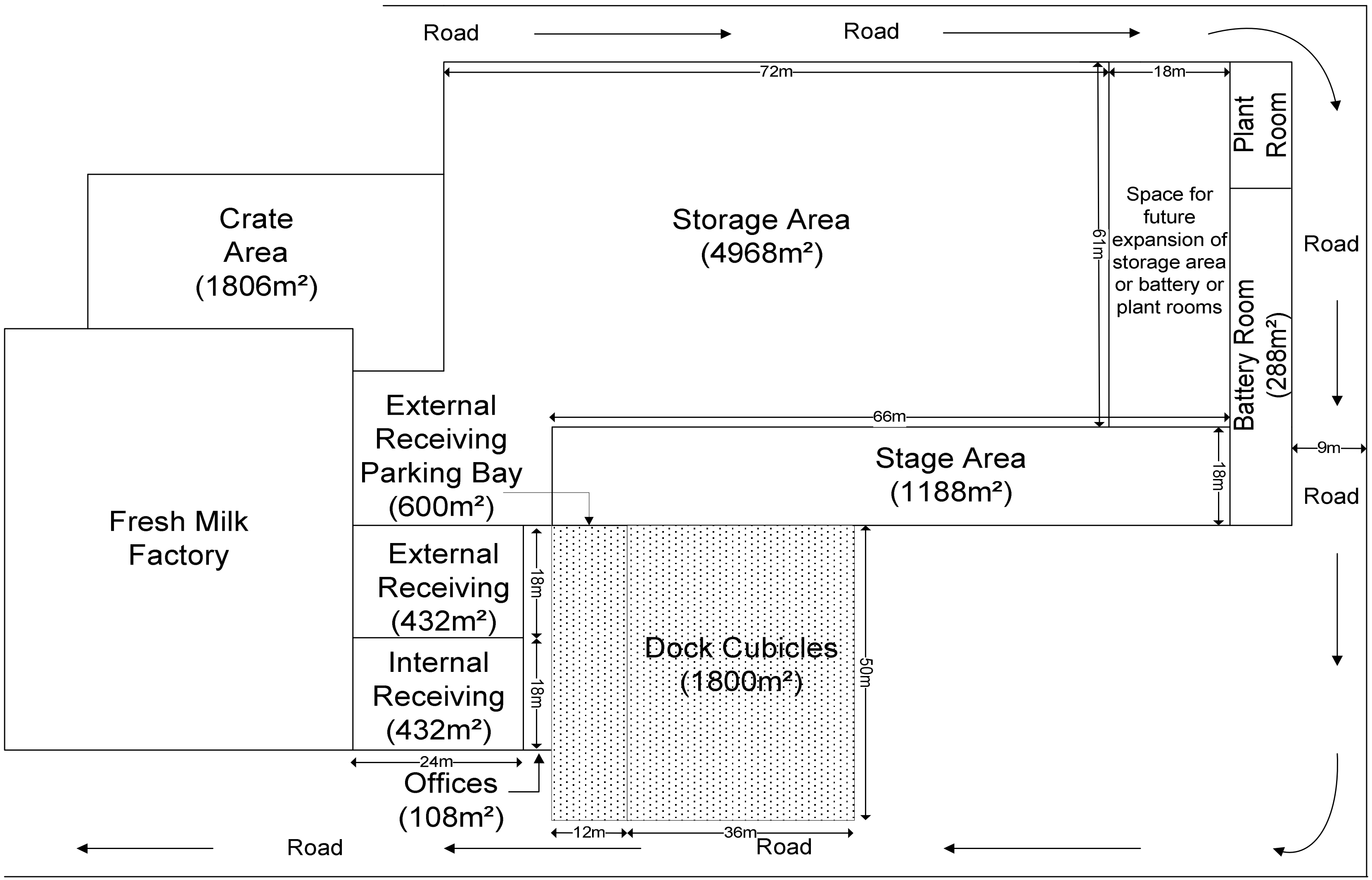


Figure 24: Layout alternative 2

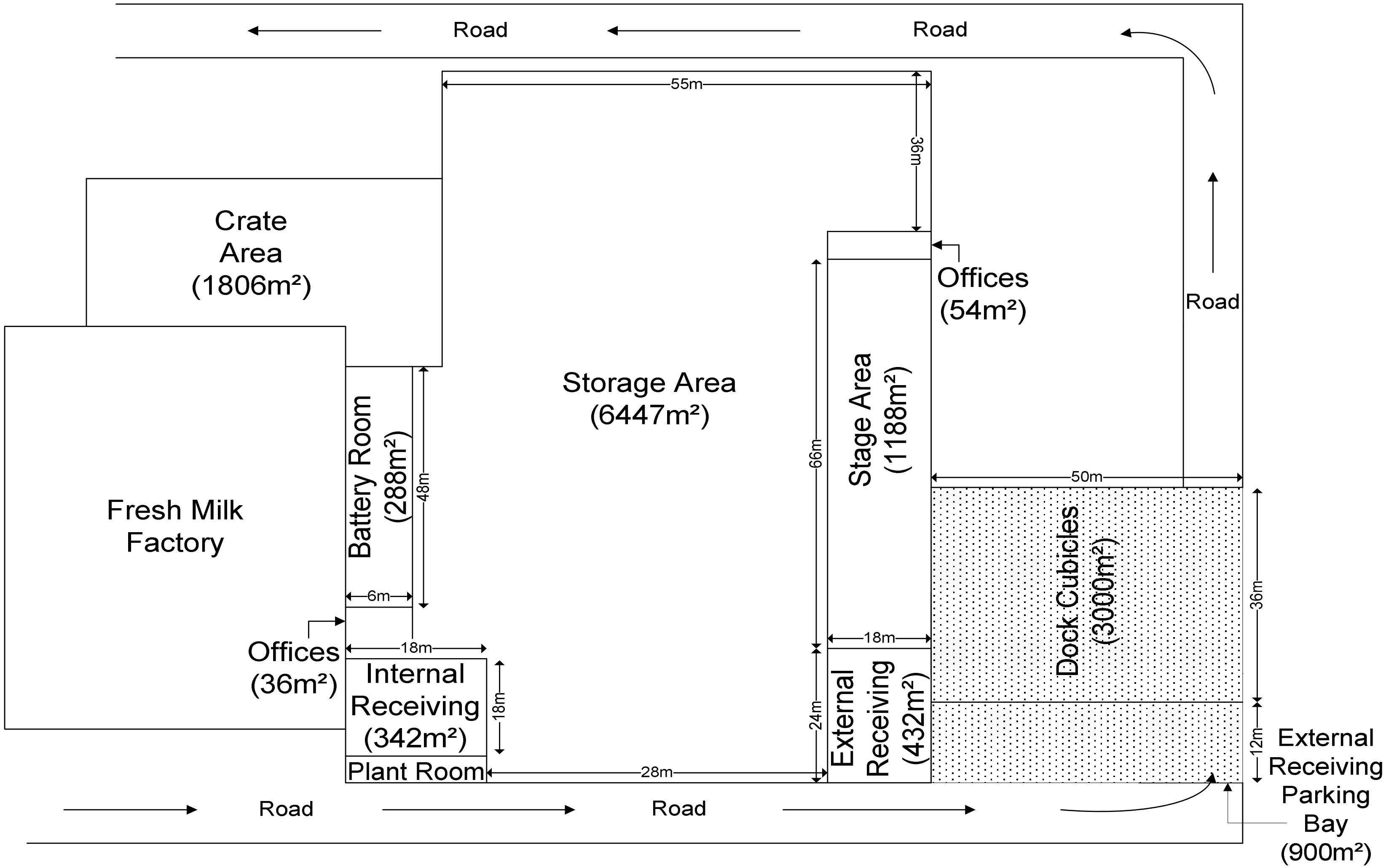


Figure 25: Layout alternative 3

8.5.1 Evaluate Facility Layout Alternatives

The dimensions of some of the departments had to be altered in the above layout alternatives in order to make all of the departments fit in to the available space. The storage space have been altered from 4356m² to 4716m², 4968m² and 6447m² in alternative one, two and three respectively. The area provided for in all three layout alternatives exceeds the space requirement for the storage area. The extra space provided for can be used for future expansion.

The dimensions of the offices have also slightly been changed. The bigger offices make provision for an increase in the personnel requirements.

Specified criteria will be used to evaluate the three layout alternatives in order to select the optimal layout. A "weighted-factor-comparison-method" will be used to measure the weight of each criterion against every layout. The following criteria were specified:

1. Space utilization
2. Management and control
3. Flow of materials
4. Internal household and employee satisfaction
5. Traffic flow around the Clayville site
6. Preferred closeness
7. Attractiveness

Each criterion (1-7) is given a weight in terms of the importance thereof. The total weights of the seven criteria should equal 100. Each alternative is then given a rating score between 0-10, where zero means that the alternative does not at all take the criterion in to consideration and ten means the layout is excellent in terms of the specific criterion.

The rating score that each alternative achieves is then multiplied by the weight of that specific criterion. The total score of each alternative is then calculated. The alternative with the highest score is then selected as the best layout for the facility.

The table below illustrates the weighted-factor-comparison-method for the three layout alternatives.

Criteria	Weights	Alternative 1	Score	Alternative 2	Score	Alternative 3	Score
1	25	9	225	8	200	7	175
2	10	7	70	8	80	7	70
3	20	9	180	7	140	8	160
4	8	8	64	7	56	8	64
5	16	8	128	9	144	7	112
6	15	8	120	7	105	7	105
7	6	9	54	7	42	8	48
Total:	100		**841**		**767**		**734**

Table 13: Outcome of the weighted-factor-comparison-method

As shown in the table above, the different scores for alternative one, two and three respectively is, 841, 767 and 734. This means that alternative one, with the highest score, is the best layout in terms of the criteria that was specified. Alternative one is thus chosen as the layout for the chilled warehouse that will be built in the future at the Clayville site.

9. Materials handling

According to Tompkins (Tompkins et al, 2003), the design of the material handling system is an important component of the overall facilities design. The integration between layout design and material handling system design is particularly critical in the design of a new facility such as the chilled warehouse.

During the facility planning process, when Muther's SLP approach was followed, the flow of products between departments was taken in to account. In a sense this then means that the handling of products was taken in to account.

One of the objectives of a materials handling system is to ease the flow of materials, or in this case products, through the facility. The storage area and stage area as well as the internal and external receiving areas were designed in such a way that all aisles face in the same direction. This layout eases the movement of reach trucks and power pallet trucks between different departments within the warehouse.

A materials handling system that has been proven to work at one or more of Clover's existing warehouses might be adjusted and implemented according to this new facility's needs or a totally new system can now be designed for this specific warehouse and layout.

9.1 Materials handling equipment

The equipment that will be used to handle, move and transport the products in the warehouse includes the following:

- Forklifts
- Reach trucks and
- Power pallet trucks.

Forklifts are used to load and unload delivery vehicles, while reach trucks transport pallets from the receiving area to the storage area and from the storage area to the stage areas. Reach trucks are designed to handle pallets and not cases of products. Reach trucks are much bigger than forklifts and for this reason it cannot be used to load or unload trucks.

As mentioned previously, the power pallet trucks are used to pick cases of products. After the power pallet truck has picked the cases of products it is stacked on to a pallet. A power pallet truck is thus the smallest of the materials handling equipment.

Different materials handling systems will have different costs associated with it. This will definitely have to be considered when deciding on a materials handling system. As mentioned in the literature study, materials handling can be defined as both an art and a science. It entails not only the moving of material but also the storing, controlling and protecting thereof (Tompkins, Tompkins et al, 2003).

10. Conclusion

The aim of this project was to reduce the strain on Clover's current distribution network by planning and building a chilled warehouse at the Clayville site that will be able to handle the future required volumes.

The existing warehouses at Clayville, together with the new, extra warehouse will now be able to pick and store more of the products that are produced on site for the 16 warehouses all around the country. This means that the products no longer have to be distributed to other warehouses in Gauteng to be stored and picked for the remaining warehouses. This results in a reduction of the strain on the current distribution network and thus achieves the aim of the project.

The new proposed facility was designed to optimize flow of materials within the facility and thus result in more effective material handling. It aims to save idle time of workers and personnel and takes future expansion in to account.

According to Tompkins (Tompkins et al, 2003), facilities planning is no longer just a science, but a strategy for navigating a competitive global economy. This project has provided Clover with a layout for a warehouse that will result in cost savings and give the company a competitive advantage.

Bibliography

Tompkins, J.A., White, J.A. (1984). *Facilities Planning.* John Wiley & Sons, Inc.

Tompkins, J.A., White, J.A., Bozer, Y.A., Tanchoco, J.M.A. (2003). *Facilities Planning,* 3rd ed. John Wiley & Sons, Inc.

Kerns, F., (1999), "Strategic facility planning", Work Study, Vol. 48, No. 5, pp. 176-181.

Gopalakrishnan, B., Li Weng, Gupta, D.P., (2003), "Facilities design using a split departmental layout configuration", Facilities, Vol. 21, No. 3/4, pp. 66-73.

Hassan, M.M.D., (2002), "A framework for the design of warehouse layout", Facilities, Vol. 20, No. 13/14, pp. 432-440.

Chien, T., (2004), "An empirical study of facility layout using a modified SLP procedure", Journal of Manufacturing Technology Management, Vol. 15, No. 6, pp. 455-465.

Wikipedia Encyclopaedia, Viewed on the 14th May 2009, http://www.wikipedia.com

Clover South Africa's website, Viewed on the 21st March 2009, http://www.clover.co.za