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Facilities planning:

Case study at Enterprise, a division of Tiger Brands.

By

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Submitted in partial fulfilment of the requirement for the degree of

BACHELORS OF INDUSTRIAL ENGINEERING

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EXECUTIVE SUMMARY

A facility planning project was conducted at Enterprise, a meat processing facility in Gauteng. The project involved the facility layout and design of the hamper room. The hamper room is defined as an area where four different hampers are manually packed with a range of 19 different products. (Each hamper consists of a mixture of some of the products.) The day after the hampers have been packed, they are sold at Enterprise's factory shops. These shops are located in Germiston and Polokwane. The hampers are in high demand and thus each hamper not packed is considered as a loss of sales.

An in-depth as-is analysis of the hamper room facility was performed. A literature study was conducted to understand the problems. This document contains recommendations to rectify issues of labour utilization, wastages, high inventory levels and inadequate facility layout. The degree to which the output of the hamper room does not conform to the demand was calculated and converted into cost of lost sales.

The problem investigation and the conceptual design revealed alternative layouts that will allow the hamper room to fulfil the required demand while addressing scheduling and safety hazard issues. Employee ownership, order replenishment schedules and alternative layouts were investigated and recommendations were made. The aim of the recommendations was to improve overall efficiency. The final recommended solution was then verified and validated.

The most significant improvement from the current facility is alternative layout 3. Implementation of this layout will ensure that the unfilled demand of 13 pallets per day is fulfilled. This fulfilment will decrease the cost of lost sales that amounted to R175 500-00 per day.

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LIST OF ABBREVIATIONS

ARD	Activity Relationship Diagram
ERP	Enterprise Resources Planning
HACCP	Hazard Analysis and Critical Control Point
HRM	Human Resource Management
JIT	Just In Time
MH	Material Handling
MRP	Material Requirement Planning
SLP	Systematic Layout Planning

1. INTRODUCTION AND BACKGROUND

1.1 Background:

Enterprise Foods was founded by a German named Hans Loeffer in 1917. This small business grew into the corporation as it is known today. For the past 96 years, Enterprise has delivered high quality, value-added meat products to emerging markets. Some of their outlets include Pick n Pay, Shoprite, Checkers, Spar, Woolworths and their own factory shops [1]. Shown in Figure 1 are some of these products which are included in the hamper.

Figure 1: Example of a hamper

Enterprise Foods have two processing facilities. One is located in Polokwane, the other in Germiston. The Polokwane plant is the largest employer in the city as it produces 328 tons of polony per month and 60.4 tons of viennas per day with the use of hi-tech automated procedures. Other products produced at the Polokwane plant includes deli loafs, spreads and canned meat. Both plants have export certifications and HACCP (Hazard Analysis and Critical Control Point) certifications.

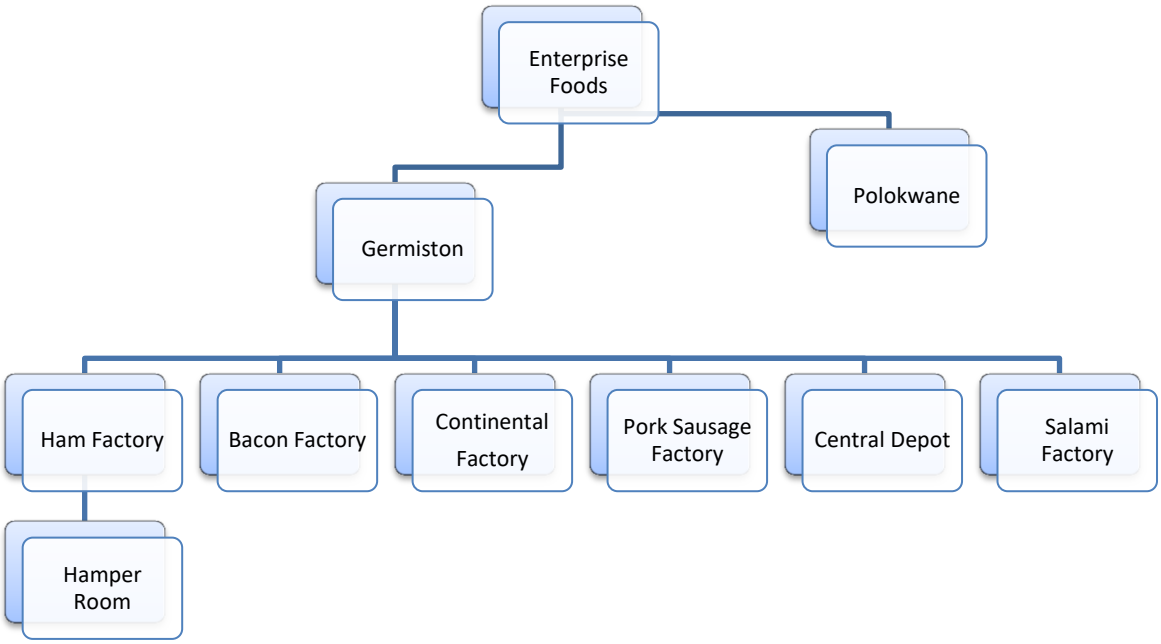


Figure 2: Structure of Enterprise Foods

The facility in Germiston consists of 6 factories. The bacon factory produces 78 tons of back, shoulder, streaky, and diced bacon on a weekly basis. The bacon factory consists of semi-automated lines of weaver slicers. The ham factory produces hams, deli roasts, beef and

poultry products at a total quantity of 160 tons per week. The other factories include Continental, Pork sausage and Salami. All these factories are connected to a Central Depot factory. Figure 2 shows the structure of Enterprise Foods. This project is based on data from the Hamper room located in the Ham Factory, situated at the Germiston plant. An analysis of the hamper room is discussed in the problem investigation. The facility is run by a unit manager and each factory in the facility is run by a production manager. The organizational structure can be seen in Figure 3.

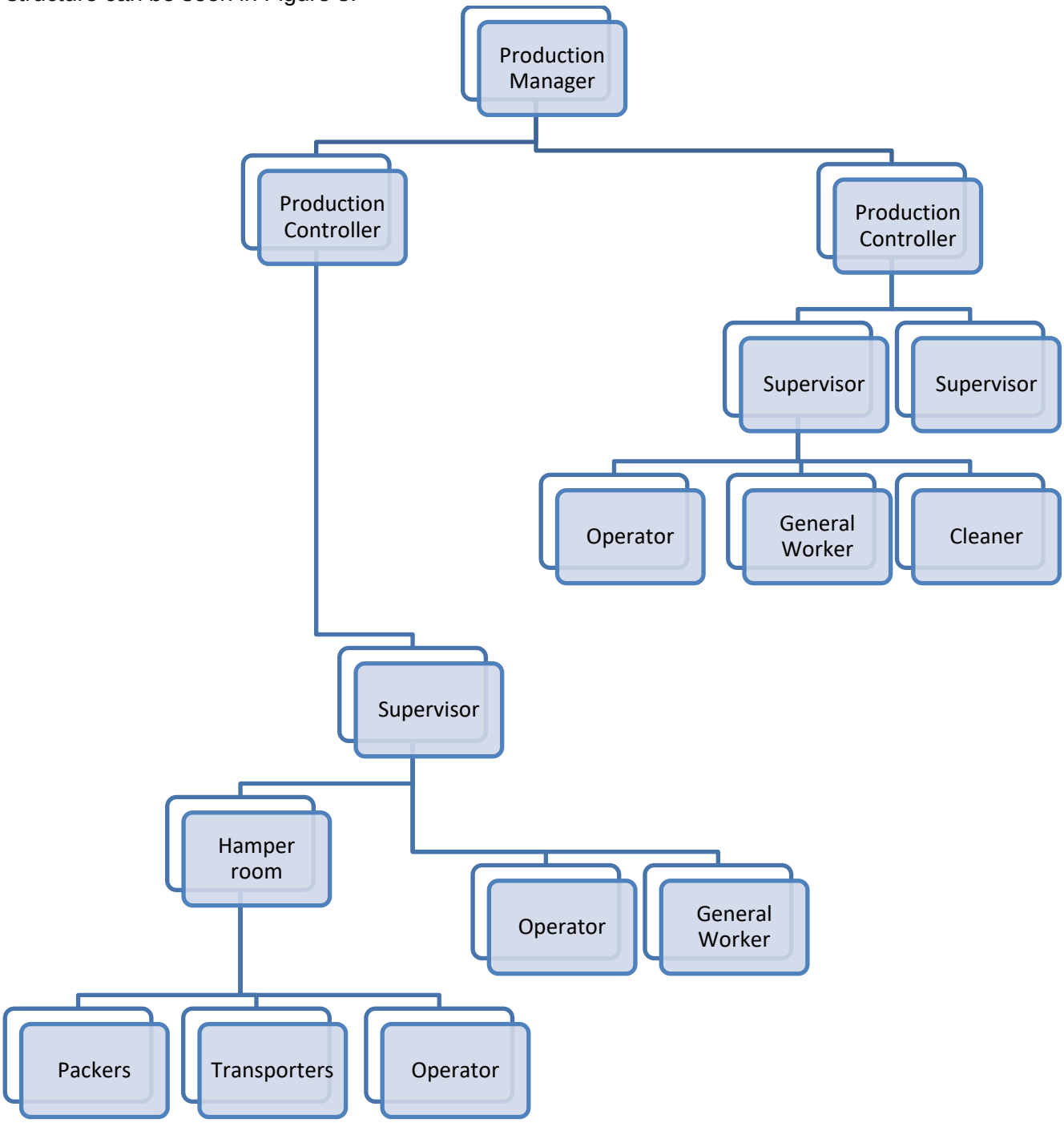


Figure 3: Organizational structure

1.2 Product Design:

When analysing the design of a facility the first aspect to consider is the product design. In this particular case, the design of the product is very simple. The product (a hamper) has four possible varieties. These four varieties consist of a mixture of 19 products.

The frequency at which the product varies is dependent on the demand. Some hamper varieties are more popular than others and thus more of these will be produced. Table 1 shows how the variety of each hamper occurs and the overall utilization of each product. Calculating the overall utilization will identify high frequency products.

Table 1: Bill of materials for different hampers

Bill of materials

		Hamper number:				
Code:	**Product:**	**1**	**4**	**9**	**11**	**Overall Product Utilization (%)**
41-0005-	Ent French Polony 1Kg	1	1	1		75
41-0120-	Ent Smoked Viennas 1Kg	1				25
41-0036-	Ent Spec Garlic Polony 500g	1	1			50
41-0852-	Ent Chopped Ham Mini Roll 500g	1				25
41-0853-	Ent Ham & Cheese Roll 500g	1	1			50
41-2203-	Ent Hamper Skinless Franks 50x375g	1	1			50
41-2204-	Ent Hamper Smoked Russians 50x357g	2	2			50
41-3466-	Ren Smoked Bacon Spread 125g	1	1			50
41-4092-	Ren Liver Spread 250g	1	1			50
41-0118-	Ent Red Viennas 1 Kg		1			25
41-0735-	Ent Ham & Tongue Roll 500g		1			25
41-0688-	Mielie-kip Chic Polony 1Kg			1		25
41-0682-	Mielie-kip Chic Polony 5x250g			1		25
41-0685-	Mielie-kip Chic Viennas 1Kg			1		25
41-0687-	Mielie-kip Chic Viennas 500g			1		25
41-1880-	Ent Chicken & Cheese Roll 500g			1		25
41-2188-	Ent Premium French Polony 1Kg				2	25
41-2189-	Ent Premium Chick Viennas 1 Kg				2	25
41-2202-	Ent Premium Snack Pack				2	25

The bill of materials will be used in the order replenishment schedule to determine whether a product is in a specific hamper and the quantity in which it occurs.

1.3 Project Rationale:

The required output for the facility is 45 pallets in a 10 hour work day with a one hour break. The pallets packed today will be sold tomorrow at either the Germiston or Polokwane factory shops. In order to fulfil the 45 pallet per day requirement, a pallet must be packed in 12 minutes. As shown in Figure 4, only 6 percent (darker bars) of the sample population adhered to this criterion.

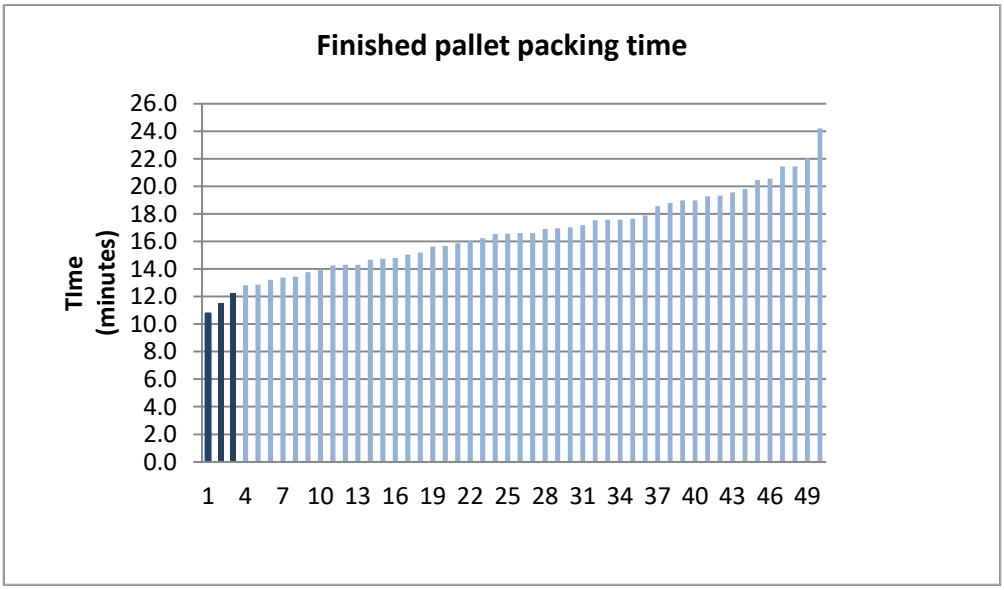


Figure 4: Finished pallet packing time

Figure 5 shows the statistical analysis of the pallet packing times. This shows a first quartile of 14.37 minutes per pallet, which is already well above the desired time per pallet. Figure 4 shows the average as 16.58 minutes and the third quartile as 18.56 minutes.

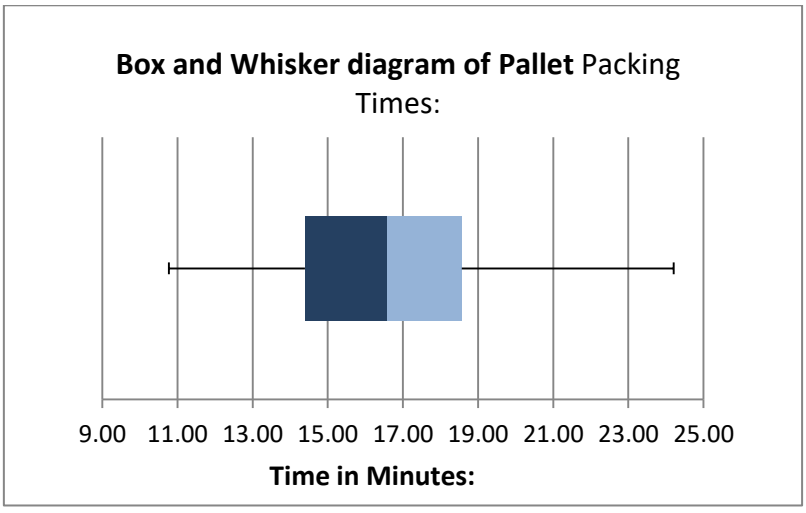


Figure 5: Box and whisker diagram of pallet packing times

If the average time it takes to pack a pallet is considered, it is calculated that 32 pallets are packed in a 10 hour work day with a one hour break. This entails that 13 pallets are needed to satisfy the demand of 45 pallets a day. In view of Table 2, the maximum cost of lost sales for the next day can be calculated as:

Highest costing hamper x unfilled demand in pallets x 75 hampers per pallet:

R 180 x 13 x 75 = R 175 500.00

And the minimum cost of lost sales will be:

R 70 x 13 x 75 = R 68 250.00

If the facility can perform as required (45 or more pallets per day) the cost of lost sales can be redeemed.

Table 2: Sales price of hampers

	Sales price: (R/ Hamper)
Hamper No 1	180.00
Hamper No 4	180.00
Hamper No 9	120.00
Hamper No 11	170.00

1.4 Project Objectives:

The aim of the project is to reduce cost of lost sales by improving the facility layout and the order replenishment schedule. This will be done by analysing the system as it currently operates, identifying problem areas and finding possible solutions for these problems. A recommendation will be made that will allow the facility to operate more productively and reduce cost of lost sales by R175 500-00 per day of unfulfilled demand.

This document discusses relevant literature needed to solve the project problem in Section 2, investigates the problem in Section 3, and addresses the various problems in Section 4 while validating the final recommendations in Section 5. The report will conclude in Section 6, relevant sources are listed in Section 7 and appendices can be found in Section 8.

2. LITERATURE REVIEW

2.1 Introduction:

Facility planning is a general term to describe several actions in relation to the design, enhancement, change or improvement of a facility. Facilities planning can be broken down into levels and these levels must collaborate to facilitate operations and continuous improvement. Figure 6 shows the hierarchical levels of facilities planning [2]:

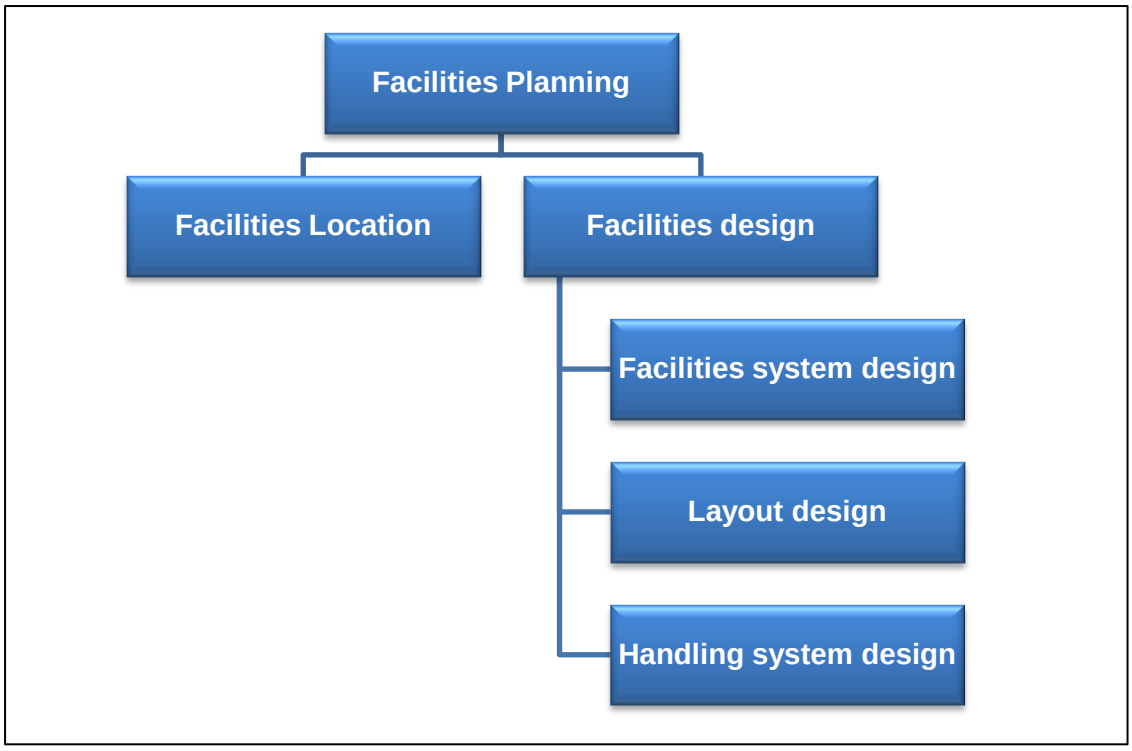


Figure 6: Facilities planning hierarchy [2]

The principles of facilities planning are to identify the needs of the facility user and plan the facility in such a way that these needs are met. Facility planning has certain objectives that allow the planner to meet the needs of the user [2]. These objectives include:

- Customer satisfaction – adhering to the needs and requirements of the customer
- Increase employee involvement
- Effective inventory management
- Cost reduction
- Maximum utilization of man, machine, material and space
- Sustainability and reliability.

The process of satisfying these objectives can be simplified into six steps:

1. The main objective and its primary supporting activities of the facility must be clearly understood and defined. If the objective is evaluated and found not sufficient, it can be redefined;
2. Investigate the problem on hand in all its facets;
3. Evaluate the required space of the facility;
4. Design and investigate alternatives;
5. Choose an alternative that best solves the problem on hand; and
6. Implement the chosen design.

Each of these objectives should be addressed and investigated in a continuous improvement cycle. This cycle is shown in Figure 7:

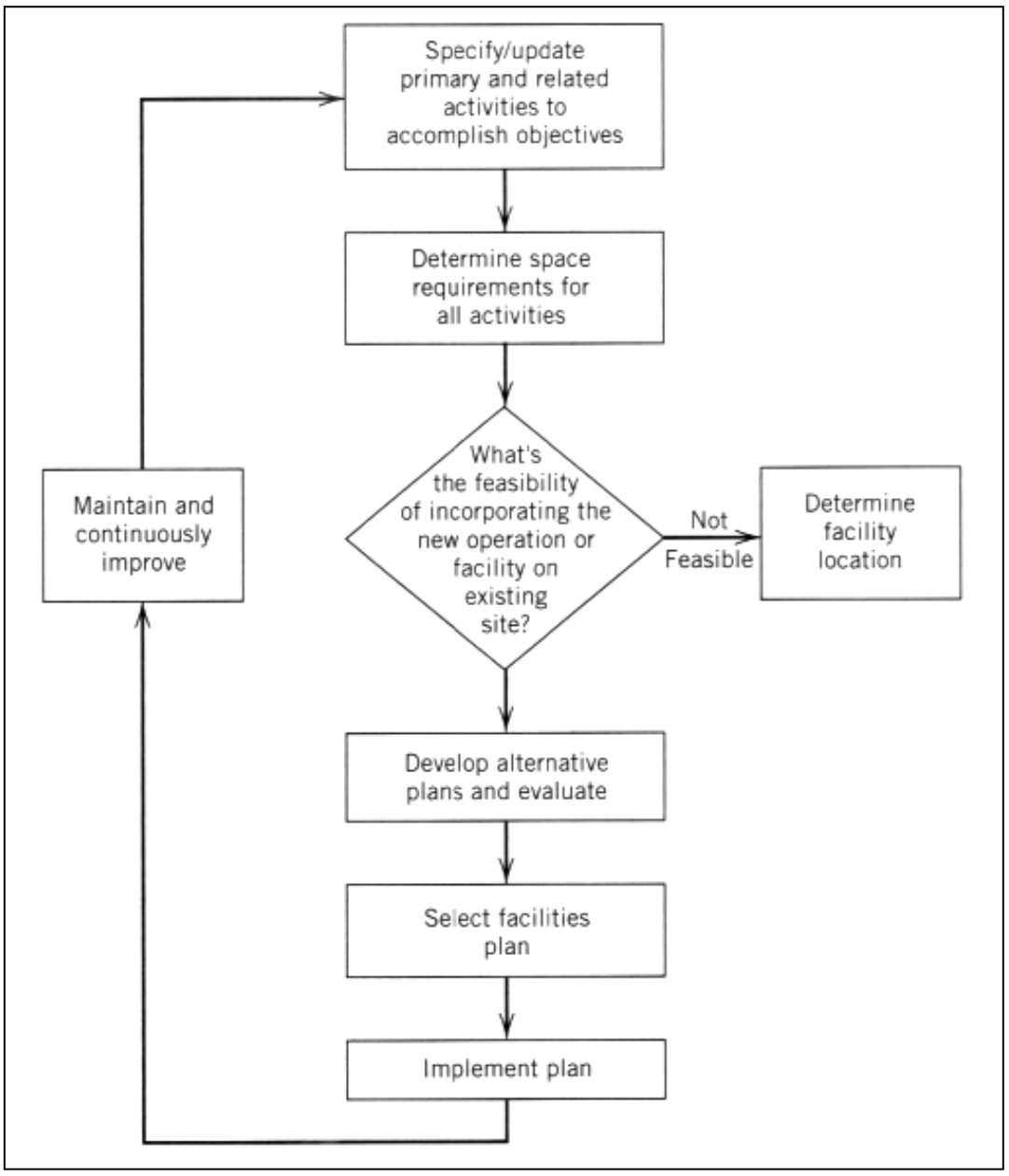


Figure 7: Continuous improvement cycle [2].

It is important to consider the impact that changes to the facility will have on different aspects of the organization. Some of these impacts include [2]:

- Handling and maintenance cost
- Employee utilization and spirits
- Management style
- Sensitivity of new design (will the facility be able to adapt to new challenges)
- Capability requirements

2.2 Labour Utilization:

A case study at a confectionary plant in the Western Cape [3] showed that the biggest problem experienced by that facility is labour utilization. This case study was also applied to a labour intensive packaging plant. The study concluded that by decreasing labour cost, operation costs can be decreased by up to 30% [4].

It is noteworthy to consider labour relations and the effect it will have on productivity. The ideologies of the labour practices need to be identified to determine how the labour force can be motivated [5]. The ideal is to create an environment where an individual is awarded choices, responsibility and a work environment where they can pursue their own goals, while acknowledging that the labourer's first duty is towards the company.

Highly motivated employees will be more productive and will carry out their work with a sense of pride [6]. There are several methods that can be applied to motivate workers [7]. These methods include acknowledgement of work done, compensation for work done and variation in tasks. Motivated employees can also be achieved by creating a supportive work environment where the needs of the employee are addressed and employees are granted opportunities to improve themselves.

There are several methods in which labour cost can be reduced. The most obvious of these will be higher labour utilization as automation is not an option. In order to increase labour utilization, employee ownership must be created. This will allow employees to take responsibility for their work and create a culture of accountability. Labour utilization can be analysed and improved by identifying wastes [8] as defined by Lean Six Sigma and determining how the facility plan contributes to these wastes.

Lean Six Sigma defines wastes as the following [9]:

- Waste of Transport: Transport of product, people or information.
  The waste of transportation can be described as the process during which a product, person or data is moved around unnecessarily. For example a product must be moved from workstation A to another while it waits to be processed at workstation A again
- Waste of Motion: Unnecessary physical movements.
  The waste of motion is defined as unnecessary movements such as picking up the same tool more than once on the same workpiece
- Waste of Waiting: Waiting for instructions (information), inventory etc.
  The waste that occurs due to waiting can occur in a lot of forms, but the greatest one is the occurrence of a bottleneck station that causes other stations to wait before processing can take place
- Waste of Inventory: Opposite of Just In Time production.
  Waste of inventory is having too much inventory on hand; this cripples your cash flow and reduces your space for actual processing
- Waste of over Production or Processing:
  Over production and processing is the work that occurs on items that has no market to be sold. For example, an order is for 100 units but 150 units were produced
- Waste of Defects:
  Defects are always a waste and should be reduced as far as possible
- Waste of Skills:
  Waste of skill occurs when a skilled person is applied to work in an area that is suitable for unskilled labour. For example a manager is doing the job of a supervisor and neglecting his/her own tasks.

Once the applicable waste has been identified, the facility can be analysed in terms of its design, layout and how it integrates man, machine and method [10]. The analysis can be

done through time studies, data from the ERP (Enterprise Resource Planning) and observations on the facility floor. This analysis will allow further waste and bottleneck detection and line balancing.

2.3 Employee Ownership

The aim is to create such a culture of ownership and responsibility that the facility (hamper room) can function directly under a production controller without supervision. This culture will be created through skills development, work values, employee involvement and a trust relationship.

Before the culture of the company can be changed it is important to identify which type of employee is present. Maslow's Hierarchy, as seen in Figure 8, was used for classification purposes [11]:

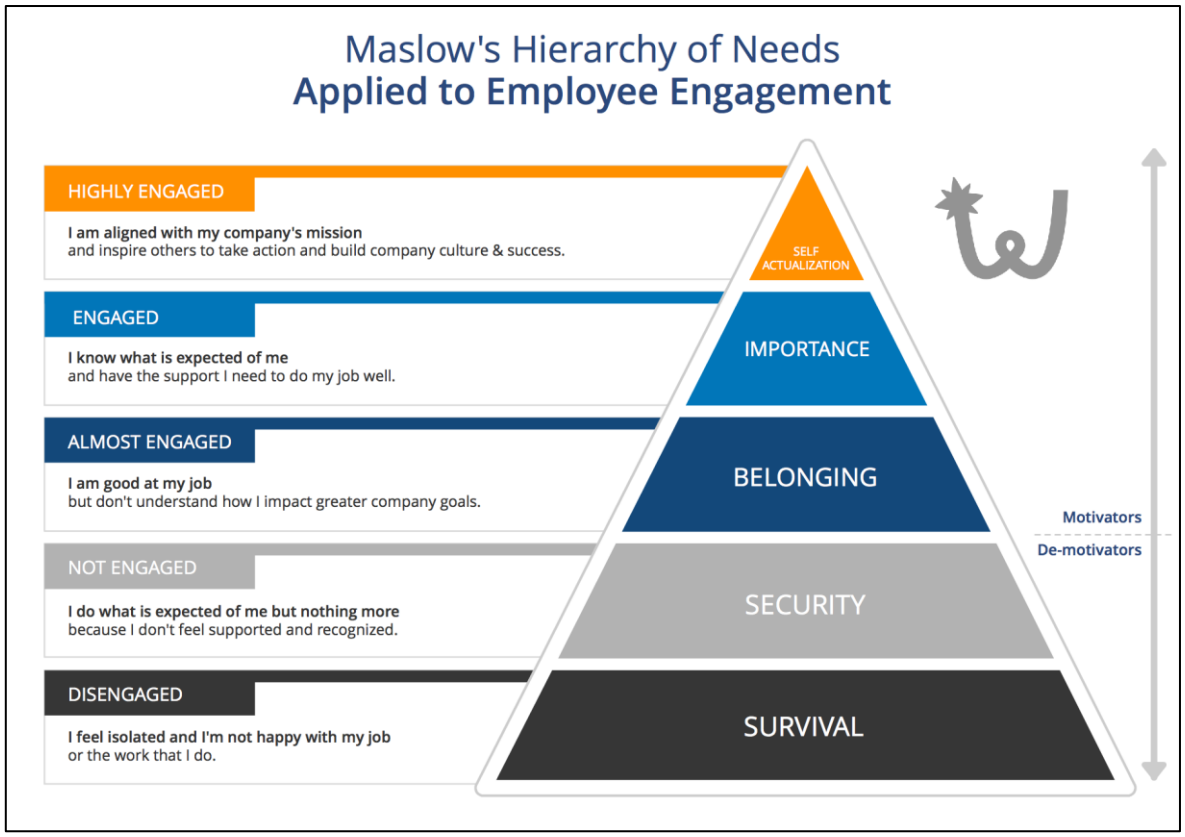


Figure 8: Maslow's hierarchy of needs [11]:

Each individual worker must be assessed to ensure that he/she is motivated in the right manner for the current position on the hierarchy. The end all employees must be at a highly engaged level.

Workforce philosophy and Human Resource Management

As discussed in the literature review, highly motivated employees perform more productively than non-motivated employees. Thus it is essential for a company to motivate their employees. Motivations in employees occur when they take ownership of their work.
Before motivation can be discussed it is important to consider the work philosophy of a company first. The work philosophy of a company explains the company's view on the value of their employees and the role that their employees play. The work philosophy will also determine the HRM (Human Resource Management) practices of that company.

There are several forms of HRM system:

- Cost reduction HRM compared to Commitment HRM and
- Internal HRM system compared to Market–type HRM.

The main explanation behind these HRM system stems from McGregor's X and Y theories on work philosophies. While the X theory believes that it is human nature not to want to work. The Y theory is optimistically the opposite. The work philosophy of which the HRM system is X theory orientated will be hostile, pressuring and punishment based. This type of system is also known for its low employee participation due to their inability to make decisions. This goes hand in hand with rigid supervision. Employees are often cynical and disappointed in their work and exhibit bad behaviour. Y theory managers are optimistic and have built a trust relationship with their employees. The manager assumes that the employees are happy to work and take initiative to finish their work. The key aspects of this type of management system are interaction, participation and communication. This management style allows employees to take part in decision making and develop their specific skill set. This development allows workers to focus on the desire for a meaningful career rather than just financial gain.

It is important to remember that a Y theory workforce philosophy cannot be built on an X theory HRM. For the employee's behaviour to change, the behaviour of management must change as the HRM conveys to the employees how management views them. If management sends a clear, positive message, workers will conform to Y theory HRM principles [12]. One of the best ways to implement a Y theory HRM is to increase employee accountability and involvement.

Employee accountability:

Accountability can be described as employees taking responsibility and ownership for their actions. In the workplace it involves taking initiative to resolve their own problems in a creative way and finishing their tasks timeously.

There are different ways to incorporate accountability into company culture:

- Involve employees in decision making:
  Allow employees to take part in the decision making process. The company empowers employees to solve problems on their own and develop with creative and innovative ideas. If employees feel they are contributing to the company on a personal level, it will increase their willingness to be responsible
- Create a trust relationship with employees:
  Employees that are in a trust relationship with their employers are more likely to create a solution rather than to put blame on someone
- Set achievable goals:
  In order to maintain morale and accountability, achievable goals must be set with appropriate key metrics to track progress. Goals help the team to focus and determine priority of tasks
- Add accountability to the company values:
  The key is to add accountability to the day to day operations of the company, even in the smallest tasks. Accountability must have consequences, whether it is in a positive or in a negative light
- Keep employees responsible for their own actions:
  When employees are treated as a group there is a tendency to melt away and never take responsibility for one's own actions. If employees are treated as individuals it is harder to hide behind a group
- Present key metrics to all employees:
  Metrics include performance of different sections. Showing the production numbers of different departments can create workplace competition. Sharing the metrics with

everybody helps the employees to see whether they have achieved their set goals or if they should try harder the next week [13].

Employee involvement

There are different strategies that can be followed to cultivate employee involvement:

- Set a common vision:
  It is important that all employees believe in the vision of the company otherwise they will not assist in executing the vision
- Training programs:
  Rather than just having the normal on the job training, add other training programs e.g. cross utilization or job shadowing programs. These programs will create fellowship amongst workers who understand each other's positions
- Continuous improvement:
  Involve employees in the calculation of key metrics for continuous improvement. This involvement will allow for creative problem solving ideas and will enable the manager to identify certain skills in specific employees. Reward and recognition is an integral part of continuous improvement [14]
- Continuing Contribution:
  Making employees stakeholders will increase their participation and involvement in the long haul as they are interested in the long term improvement of the company. This action can be done by reducing the company's hierarchal structure into a flatter structure which will insure open communication amongst all stakeholders
- Shared Contribution:
  Shared contribution can be involvement on the board or involvement in a bargaining council or trade union
- Singular Contribution:
  Singular contribution includes decision making in teamwork, small group activities and taking initiative [15].

2.4 Just In Time (JIT):

Part of the lean toolkit to optimize a process is the JIT (Just-In-Time) principle. JIT will allow reduced process inventories which will result in more space on the facility floor. A disadvantage of JIT is the fact that it will require highly reliable suppliers [16].

By implementing JIT, management will be able to streamline the process with little waste. Key factors of JIT are obtaining reliable suppliers and enter a long term agreements with them. A good relationship with a supplier will simplify the implementation of JIT.

When JIT is applied on a small scale, scheduling of materials is extremely important as the key objective of JIT is zero inventories. Figure 9 describes the JIT philosophy:

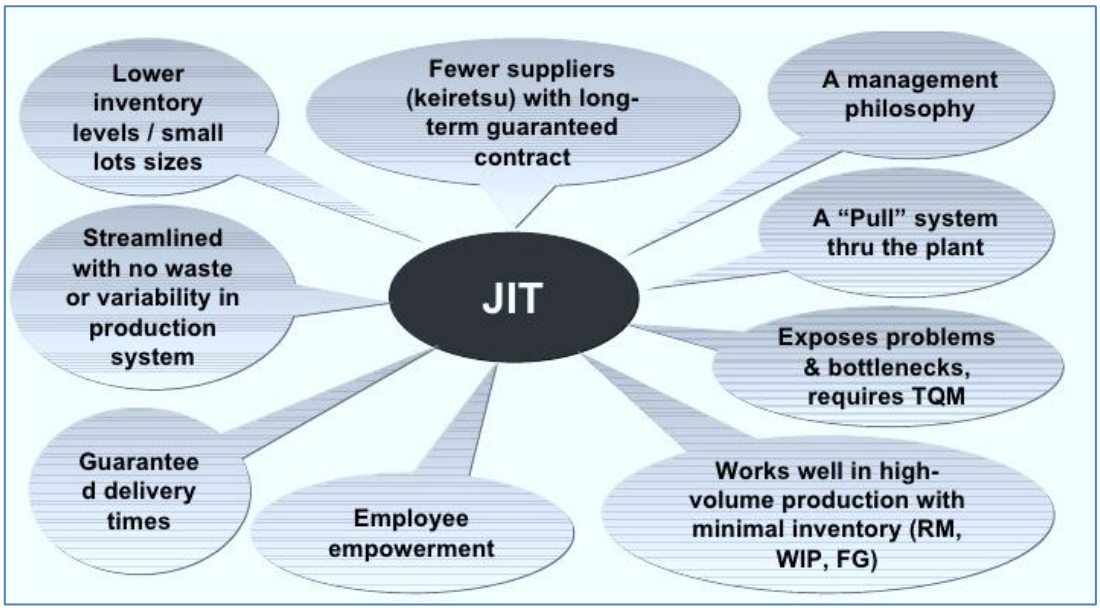


Figure 9: JIT philosophy [17]

JIT goes hand in hand with the implementation of Kanban. In simple terms Kanban is defined as a visual system that activates an action. This method is highly effective in inventory management. Each piece of inventory has a clearly marked place, this way it is easy to see when inventory is running low. Another principle of Kanban is changing the system form a push system to a pull system. A push system can be described as a system in which resources are replenished at a rate determined by forecasts and schedules and not the demand by customers. A pull system is in direct contrast with a push system, as the replenishment of inventory is determined by the demand for products. Figure 10 shows the difference between a pull and push system.

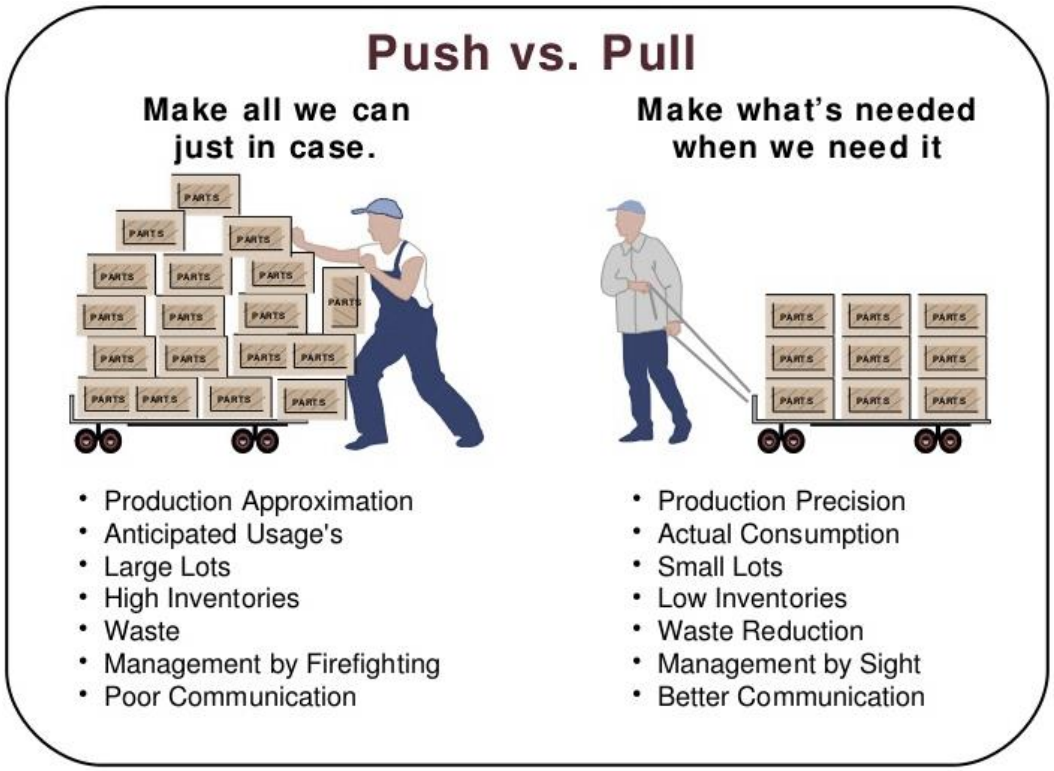


Figure 10: Difference between a pull and push system [18]

By applying JIT in this way, the need for MRP (Material Requirement Planning) is removed [19].

2.5 Facility Planning:

An attribute to optimizing a facility is to increase specified requirements on inputs such as product, process and schedule designs [2]. These designs must adhere to layout characteristics, material handling requirements and storages strategies.

There are a few basic steps to follow when a facility is being planned. There are three major layout planning procedures as discussed in Thompkins et al [2]. The first is Apple's Plant layout procedure. The procedure consists of 20 sequential steps that must be followed. These steps include procurement and analysis of data, requirement analysis, and a master layout. Another layout procedure is that of Reed. Reed's procedure emphasizes the importance of a layout planning chart. A layout planning chart includes the flow of processes, the standard time for processes, machine selection, human resources and material handling requirements. One popular process is Muther's SLP (Systematic Layout Planning) procedures with the steps for this procedure shown in Figure 11:

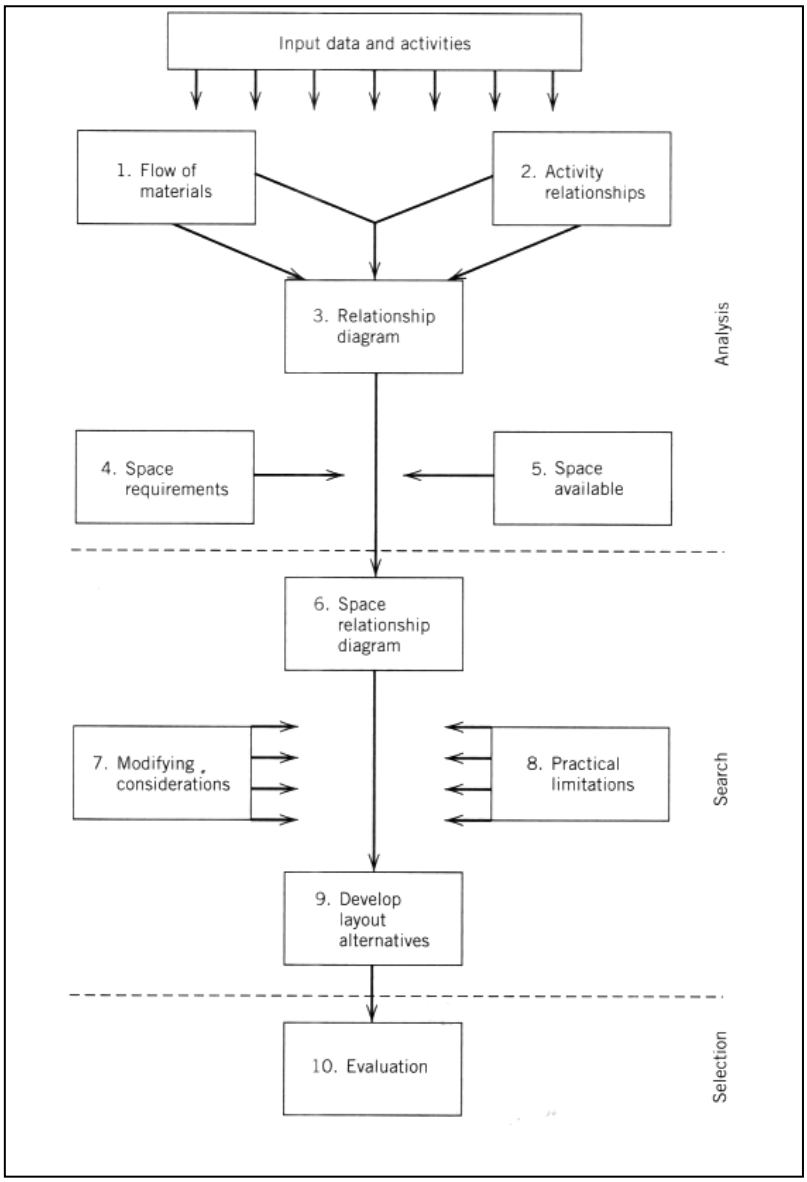


Figure 11: Systematic layout planning [2]

For each of the three techniques considered there are certain advantages, disadvantages and limitations involved in the applications. The characteristics and how they can be differentiated are discussed in Table 3.

Table 3: Layout planning procedures [2]

	Procedure:		
Attribute:	Apple	Reed	Muther
Data	Procures and analyse basic data	Production requirements and time standards are analysed	Data is an input of the procedure
Process	Designing of process	Flow processes are analysed	No provision made
Flow of materials	Plans the flow of materials	Incorporates flow of materials	Analyse flow of materials
Material Handling (MH)	General MH is considered.	Requirements are established	No provision made
Equipment	Requirements are calculated	Designated	No provision made
Workstations	Designed	Designed	No provision made
Grouping	Related operations are grouped	No provision made	No provision made
Activity relationships	Designed	No provision made	Determined (Activity relationship diagram)
Storage	Requirements are determined	Storage requirements are analysed	No provision made
Services and auxiliary activities	Provisioned for	Plant services are surveyed, isle width, personnel facilities and office necessities are determined	No provision made
Space requirements	Calculated	No provision made	Space requirements for each activity is considered
Activity allocation	Space is divided up between activities	No provision made	Available space is merged with required space. (space relationship diagram)
Layout alternatives	Master layout is constructed	No provision made	Different layouts are developed
Evaluations	Layouts are evaluated	No provision made	Layouts are evaluated
Future	Implementation and continuations.	Provision made for future expansions	No provision made

Muther's SLP is more quantitative due to the applicable diagrams.

The SLP procedure starts with the analysis of system inputs and activities. This analysis includes the flow of materials and the relationship between activities. This data is combined to form the activity relationship chart. The process of the activity relationship chart can be seen in Figure 12.

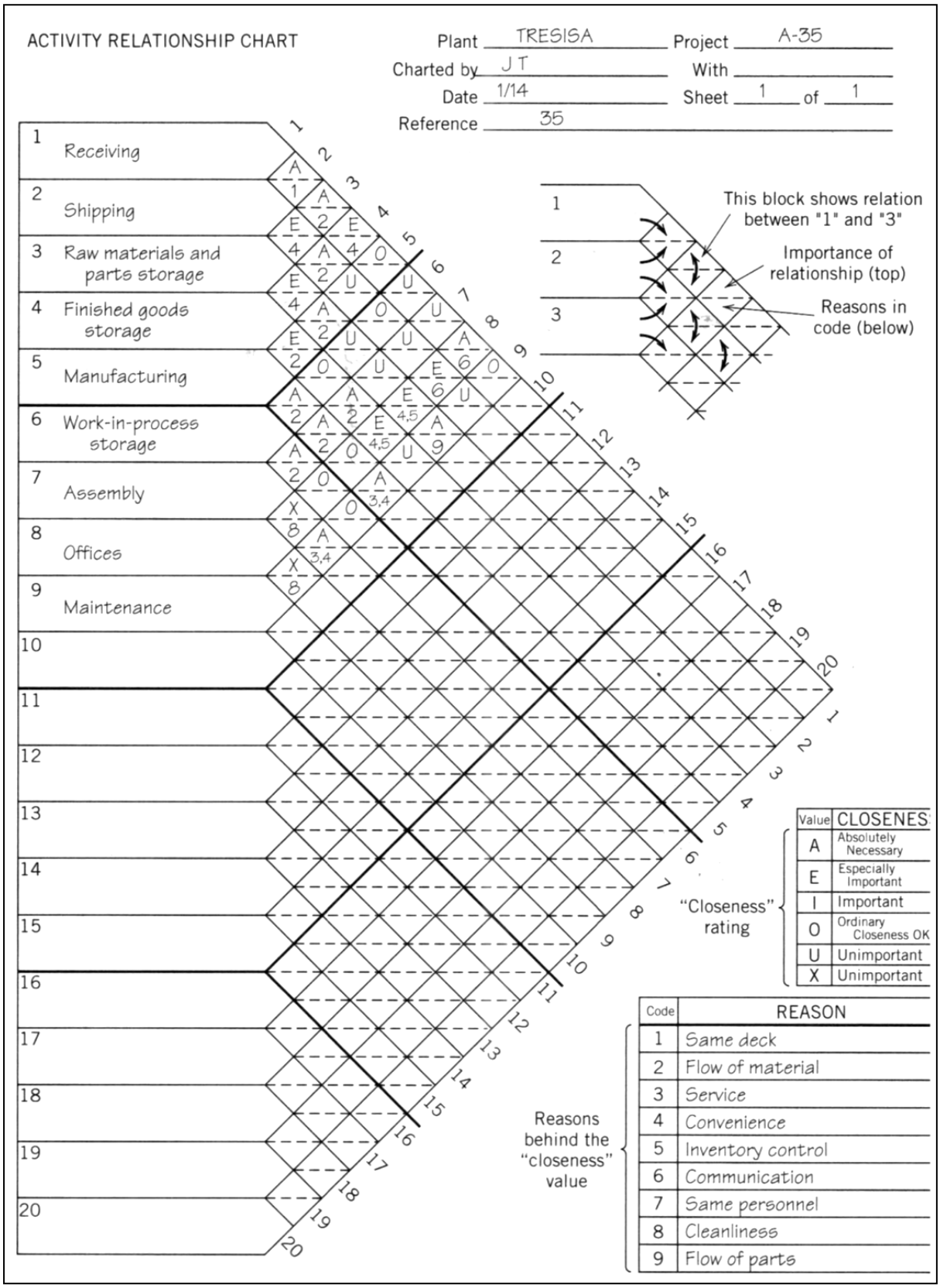
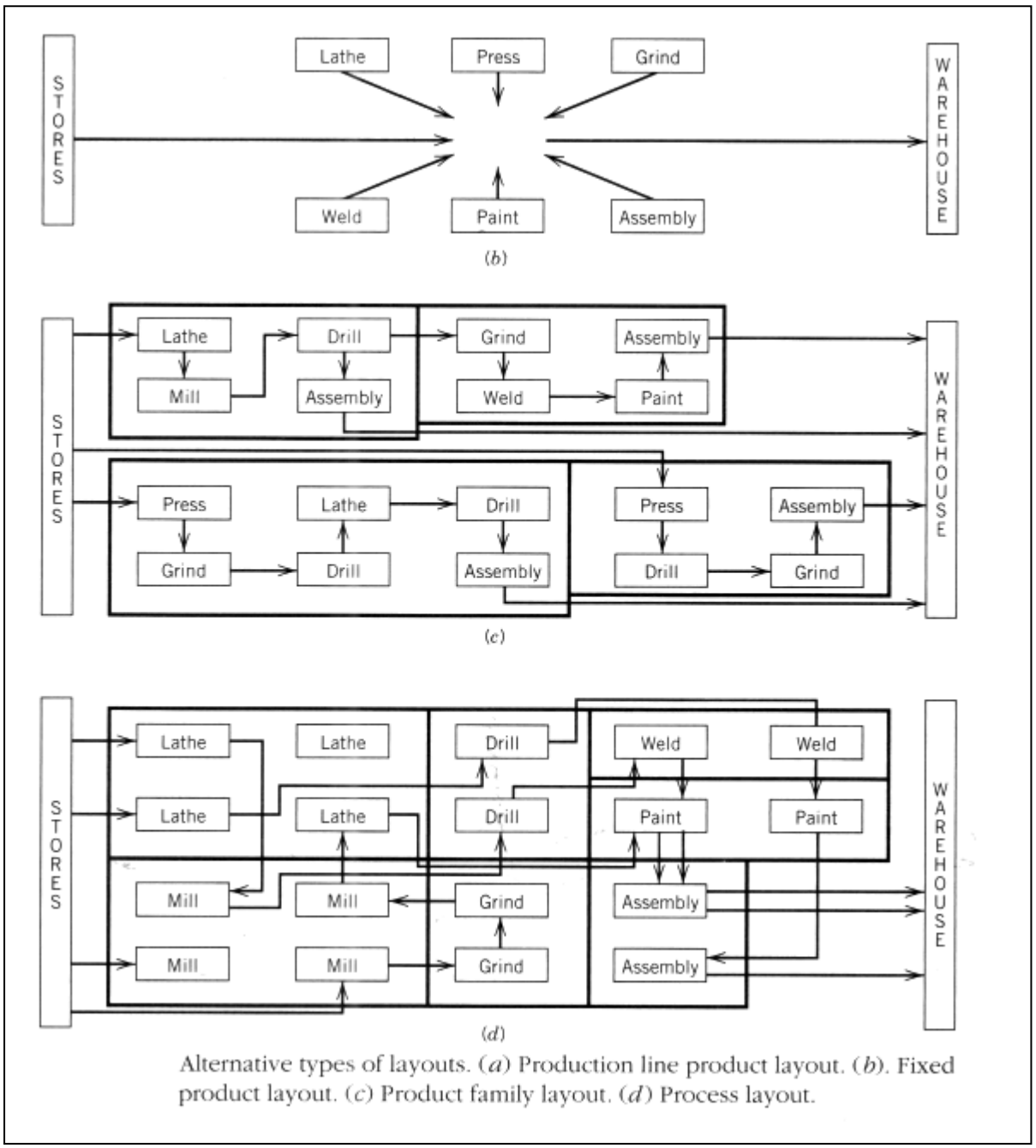


Figure 12: Activity relationship chart [2]

Through this diagram the available space can be compared to the space requirements. Once this has been compared a space relationship diagram is drawn. The diagram allows the planner to consider practical limitations and modify the layout to create alternatives [2].

Part of the SLP will be to analyse layouts. Layout characteristics will include the type of layout, being production line product layout, fixed product layout, product family layout or process layout. These layouts are shown in Figure 13.



Alternative types of layouts. (*a*) Production line product layout. (*b*). Fixed product layout. (*c*) Product family layout. (*d*) Process layout.

Figure 13: Alterative layouts [2]

Material handling requirements depend on line flow patterns, whether it is a straight-line flow, u-flow, S-flow, W-flow or O-flow. These flow patterns are shown in Figure 14.

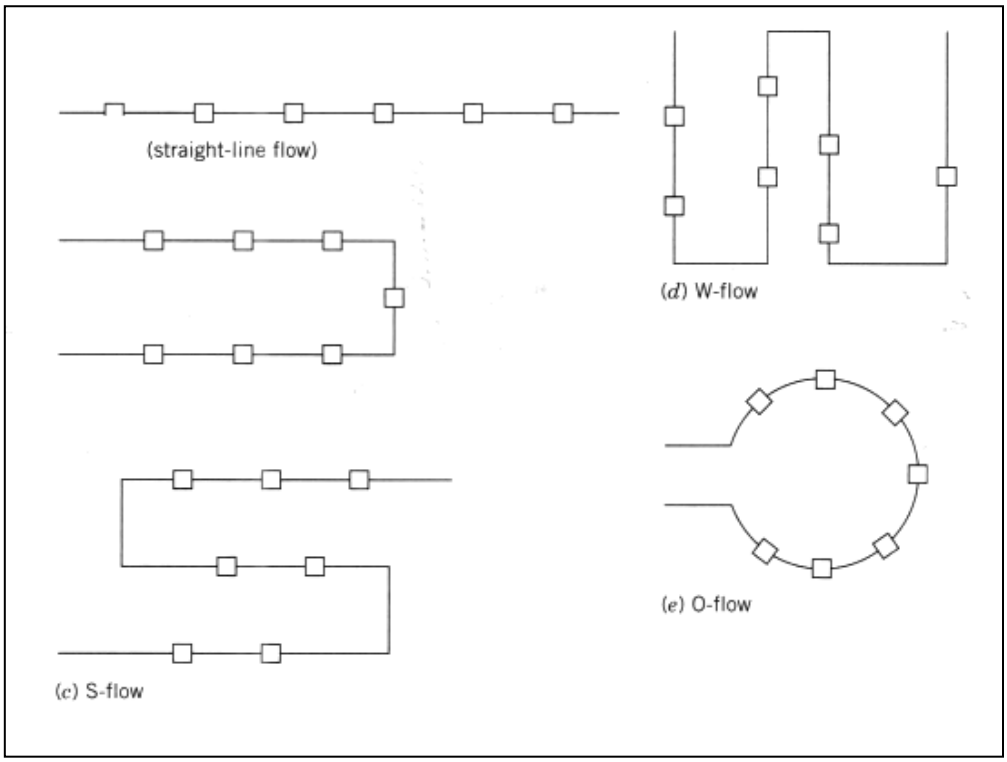


Figure 14: Flow patterns [2]

It is important to ensure effective flow within workstations first, then within the department and then between different departments. The design can then be applied for a labour intensive manual packing line. A layout to consider is a JIT – layout. The layout can either consist of an assembly line layout or a job shop layout, with the main objective to simplify material handling requirements [20].

The alternative layouts will be determined using an activity relationship chart, shown in Figure 15 and alternative block diagrams, shown in Figure 16. The activity relationship will determine which activity "departments" must be next to each other, which can be next to each and which departments cannot be next to each other.

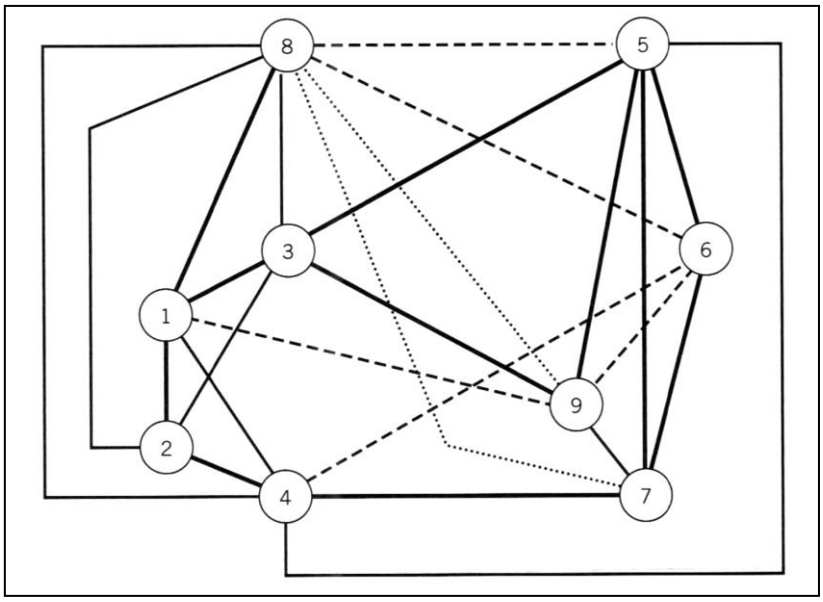


Figure 15: Activity relationship chart [2]

The closeness of the activities can be due to the sequential flow of materials, safety reasons, sharing of the same labour, having the same input or output, sharing of equipment or to ease communication [2].

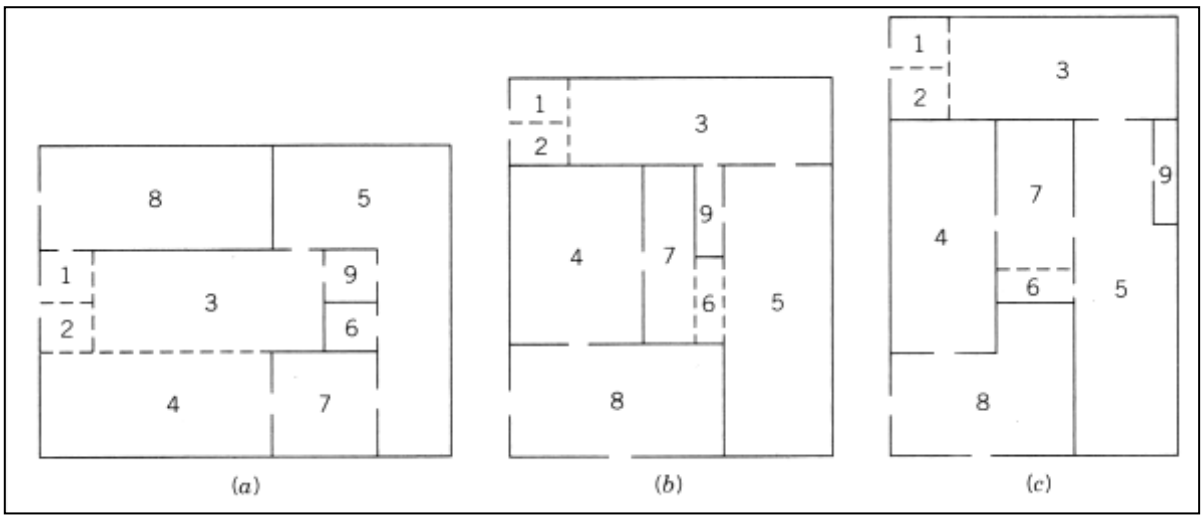


Figure 16: Alternative block diagrams [2]

Thereafter the space requirement diagrams are drawn. These diagrams show the flow of activities and their closeness but on a scale model of the floor space that each activity occupies. Advantages of using these diagrams are as follows:

- It clearly shows the flow of materials
- It is easily understandable by all stakeholders
- It is an essential tool in facility design [21].

The block diagram will be used to determine a basic facility layout that fulfils the requirements of the ARD (Activity Relationship Diagram). The block diagram is fairly easy to construct and it can thus be used to create a range of alternatives. These alternatives are created based on the ARD and the requirements of management while allowing for limitations also. The block diagrams allow the change of the line flow and the layout type. Some limitations can include height restrictions, number of electrical points and size of the facility. The effect of the layout changes can be determined using management accounting principles of decision making. The effect can also be determined by comparing differential costs, opportunity costs and sunk costs of the different layouts [22].

2.6 Evaluating Alternatives:

Once the alternative diagrams have been completed, each alternative must be evaluated before a selection can be made. Tompkins et al [2] describes three different ways in which alternatives can be evaluated:

- Comparing advantages and disadvantages
- Ranking
- Comparison through weighted factors.

Comparison through advantages and disadvantages is the most basic of the three alternatives. For this alternative the planner must objectively look at each alternative layout and discuss its component and decide whether it is positive or negative. The great challenge with this alternative is being objective and not be inclined to favour specific alternatives. The best way to ensure that the comparison is done objectively, is to assemble a team to participate in the evaluation [2].

The ranking comparison allows the planner to evaluate each alternative layout by comparing it to a common set of standards. These standards describe the performance of a factor within the layout. Example standards include:

- Poor performance
- Fails to meet requirements
- Adequate performance
- Meets requirements
- Exceptional performance
- Exceeds requirements.

Ranking, like comparison through advantages and disadvantages has its own problems. There is no way to ensure that all factors have been covered and no method to prevent that too many factors have been covered. The solution is to implement the ranking with another method of evaluation [2].

Comparison through weighted factors is the last of the three evaluating alternatives. What differentiates it from the above mentioned alternatives is that a numerical value is assigned to each factor. Factors are still ranked, but now each one has a value proportionate to the other. When factors are compared it will now be easier to see to what extent they differ [2].

2.7 Data Gathering:

During the gathering of information at the plant, it is important to obtain accurate data. Observing workers might lead to improved performance that is not the true data due to the Hawthorne effect. The Hawthorne effect gives rise to the fact that workers' productivity will increase if they are observed, no matter the environment [23]. To reduce this effect data must be gathered over a long period of time to ensure that employees behave as they would normally do.

In the following sections, Section 3 and Section 4, relevant literature will be applied to investigate and solve the problem.

3. PROBLEM INVESTIGATION

Facility description:

Four types of hampers are packed in the hamper room. The supervisor receives an order for a certain number of a specific hamper at the start of each day.

Pallets containing stock are brought from Central Depot and stacked in the hamper room from right to left, at the back of the room. Once a pallet has been stacked and the stacking of the next row has begun, that pallet cannot be moved as the rows between pallets are not wide enough to remove or replace a pallet.

Individual boxes are removed from pallets and taken to the packing stations. Each packing station requires a different product type. The filled hamper pack is sealed with a sealer at the bottom of the pack. Once sealed, 3 hampers are packed into a crate. 25 crates are packed onto a pallet. The pallet is wrapped and hauled to the docking station near Central Depot. A pallet is considered completed when it is wrapped.

Observations made on the facility floor gave rise to the following issues:

- Low labour utilization: Due to the location of the packing stations and electrical plugs, only four people can pack hampers, a maximum of one person can seal the hampers and only one person can pack pallets. The rest of the labour assigned to the labour room removes inventory from boxes to top up packing stations and transport pallets.
- Low facility utilization: Large areas of the facility are covered with inventory that will not necessarily be used that day.
- Low machine utilization: Currently only one of the two sealers is being used.
- Safety hazards: The nearly 8.3˚ slope at the entrance of the facility is a safety hazard due to the fact that loaded pallets tend to speed down from it. It takes a minimum of 3 men to haul a loaded pallet up the slope.
- Wastes: Inventory comes in sealed boxes; every box must be opened, emptied and folded. This leads to a messy untidy facility, because folding empty boxes is not priority, and these empty boxes take up space and time.
- No quality control takes place. Hampers are packed, but there is no system in place to ensure that the correct amount and type of products have been added.
- Lack of motivation. Working pace slows when there is no direct supervision.

The hamper room is located in the Ham factory. It receives stock from 2 factories in the Germiston plant and the rest from the Polokwane plant. The hampers are allocated for the factory shop at Germiston and for the factory shop at Polokwane. During the first and the last week of the month, higher quantities of hampers are required. Currently there is not a fixed facility layout, and production quotas are not met even though more people are assigned to pack hampers. This is due to a lack of communication between plants regarding the supply of stock and hampers and the under-utilization of labour. The space in the hamper room and the people assigned to the hamper room are under-utilized and thus low levels of productivity are recorded. The company is in need of a facility plan that will reduces labour costs and increase production. Figure 17 shows the current facility layout.

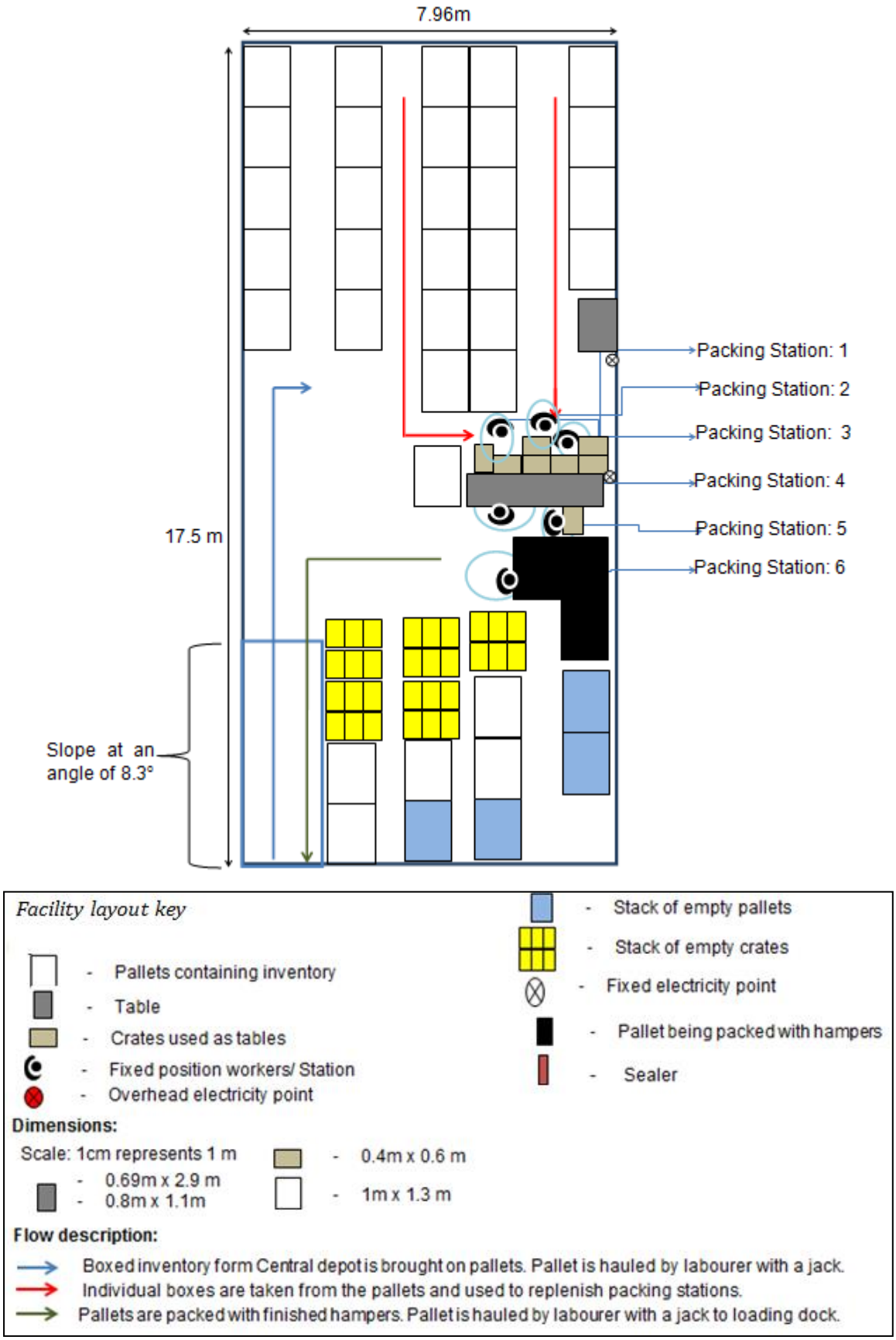


Figure 17: Current facility layout

In the section to follow, Section 4, each aspect of the problem will be addressed, alternative solutions will be suggested, evaluated and a recommendation will be made.

4. FACILITY DESIGN

4.1 Order Replenishment Schedule:

Facility handling mostly focuses on the material handling of raw material that makes up the product. The major issue the company is experiencing with material handling, is scheduling, especially the arrival of raw materials (the different products). The equations below will allow the company to determine the exact number of pallets required to fulfil the given demand.

Let:

D_i ≙ Demand per 3 day cycle for hamper i (in pallets)
$i \in \{1,., 4\}$

Q_j ≙ Quantity of product j in boxes on a pallet
$j \in \{1,.., 19\}$

M_j ≙ Quantity of product j in a box
$j \in \{1,.., 19\}$

S_j ≙ Amount of product j needed to fulfil demand for hamper i
$i \in \{1,.., 4\}$ and $j \in \{1,.., 19\}$

P_j ≙ Total number of pallets of product j needed to fulfil the demand for all hampers in a 3 day cycle.
$j \in \{1,.., 19\}$

N_{ij} ≙ The quantity of product j in hamper i
$i \in \{1,.., 4\}$ and $j \in \{1,.., 19\}$

I_i ≙ The inventory remaining from the previous cycle
$i \in \{1,., 4\}$

$$\mathbf{S_j = \sum_{i=1}^{4} [D_i \times 75 \times N_{ij} - (I_i \times M_j)]} \qquad \mathbf{j \in \{1,.., 19\}}$$

$$\mathbf{P_j = S_j \div (Q_j \times M_j)} \qquad \mathbf{j \in \{1,.., 19\}}$$

The cycle is calculated as a three day cycle. The aim is to have a fully functioning JIT process, but due to a lack of reliability on the part of suppliers, a three day cycle is the shortest possibility.

The formula was converted into an Excel Spreadsheet. The inventory on hand at the end of the day can be entered for each cycle. The spreadsheet contains a tab where the demand for each hamper can be entered as number of pallets. Once this data has been entered, the spreadsheet will automatically generate the order replenishment schedule in pallets. Inventory must be entered on regular bases. The inventory from the previous cycle will determine the order quantity of the next cycle. The inventory, demand and bill of materials together are used to create the order quantity form. This form can be directly forwarded to the suppliers. The order specifies for which cycle the order is valid for as it changes the

inventory that is used in the formula. The order form also specifies the date of order and the date of delivery. Screenshots from the Excel Spreadsheet can be seen in Figure 18, 19 and 20 as well as Appendix B.

Production Quantities: Hamper Room

Date:

Cycle	Monday - Wednesday
Production Type	**Production Quantity** (Number of pallets)
Hamper 1	11
Hamper 4	12
Hamper 9	14
Hamper 11	

Figure 18: Screenshot of input

Inventory

Code	Product:	Number of boxes							
		Cycle A				Cycle B			
		Monday	Tuesday	Wednesday	TOTAL	Thursday	Friday	Saturday	TOTAL
41-0005-	Ent French Polony 1Kg	142			142				0
41-0120-	Ent Smoked Viennas 1Kg	1			1				0
41-0036-	Ent Spec Garlic Polony 500g	141			141				0
41-0852-	Ent Chopped Ham Mini Roll 500g	12			12				0
41-0853-	Ent Ham & Cheese Roll 500g	1			1				0
41-2203-	Ent Hamper Skinless Franks 50x375g	4			4				0
41-2204-	Ent Hamper Smoked Russians 50x357g	4			4				0
41-2137-	Ren Smoked Bacon Spread 125g	42			42				0
41-3466-	Ren Smoked Bacon Spread 125g				0				0
41-2140-	Ren Liver Spread 250g				0				0
41-4092-	Ren Liver Spread 250g				0				0
41-0118-	Ent Red Viennas 1 Kg				0				0
41-0735-	Ent Ham & Tongue Roll 500g				0				0
41-0688-	Mielie-kip Chic Polony 1Kg				0				0
41-0682-	Mielie-kip Chic Polony 5x250g				0				0
41-0685-	Mielie-kip Chic Viennas 1Kg				0				0
41-0687-	Mielie-kip Chic Viennas 500g				0				0
41-1880-	Ent Chicken & Cheese Roll 500g				0				0
41-2188-	Ent Premium French Polony 1Kg				0				0
41-2189-	Ent Premium Chick Viennas 1 Kg				0				0
41-2202-	Ent Premium Snack Pack				0				0

Figure 19: Screenshot of inventory

Order for cycle: MON - WED

Date:

Date To be delivered:

Product Code	Product description	Whole Number of pallets	Number of pallets
41-0005-	Ent French Polony 1Kg	4	3.083
41-0120-	Ent Smoked Viennas 1Kg	2	1.091
41-0036-	Ent Spec Garlic Polony 500g	2	1.027
41-0852-	Ent Chopped Ham Mini Roll 500g	1	0.655
41-0853-	Ent Ham & Cheese Roll 500g	2	1.369
41-2203-	Ent Hamper Skinless Franks 50x375g	1	0.986
41-2204-	Ent Hamper Smoked Russians 50x357g	2	1.971
41-2137-	Ren Smoked Bacon Spread 125g	1	0.345
41-3466-	Ren Smoked Bacon Spread 125g	1	0.362
41-2140-	Ren Liver Spread 250g	1	0.767
41-4092-	Ren Liver Spread 250g	1	0.719
41-0118-	Ent Red Viennas 1 Kg	2	1.190
41-0735-	Ent Ham & Tongue Roll 500g	1	0.714
41-0688-	Mielie-kip Chic Polony 1Kg	2	1.167
41-0682-	Mielie-kip Chic Polony 5x250g	1	0.375
41-0685-	Mielie-kip Chic Viennas 1Kg	2	1.667
41-0687-	Mielie-kip Chic Viennas 500g	1	0.568
41-1880-	Ent Chicken & Cheese Roll 500g	1	0.729
41-2188-	Ent Premium French Polony 1Kg	0	0.000
41-2189-	Ent Premium Chick Viennas 1 Kg	0	0.000
41-2202-	Ent Premium Snack Pack	0	0.000

Figure 20: Screenshot of output

Having the order quantity form, it was noted that to satisfy a 45 pallet per day demand over a three day cycle, significant storage space would be needed. Mock data showed that 80 pallets of inventory will be needed for the three day cycle, but the facility only has space for 20. Applying the three day cycle will require temporary storage for the other 60 pallets. Thus alternative storage space must be investigated.

4.2 Layout Design:

The main objective when investigating a facility is to design or redesign activities which best support the business objectives of that facility. The investigation can be focused on facility location or facility design. As the facility location is fixed in terms of this project, the facility design will be analysed.

4.2.1 Activity Relationship Chart

The activity relationship diagram in Figure 21 shows a visualised model of the closeness between different activities within the same department. The closeness ratings and the reasons for closeness are defined in Table 4.

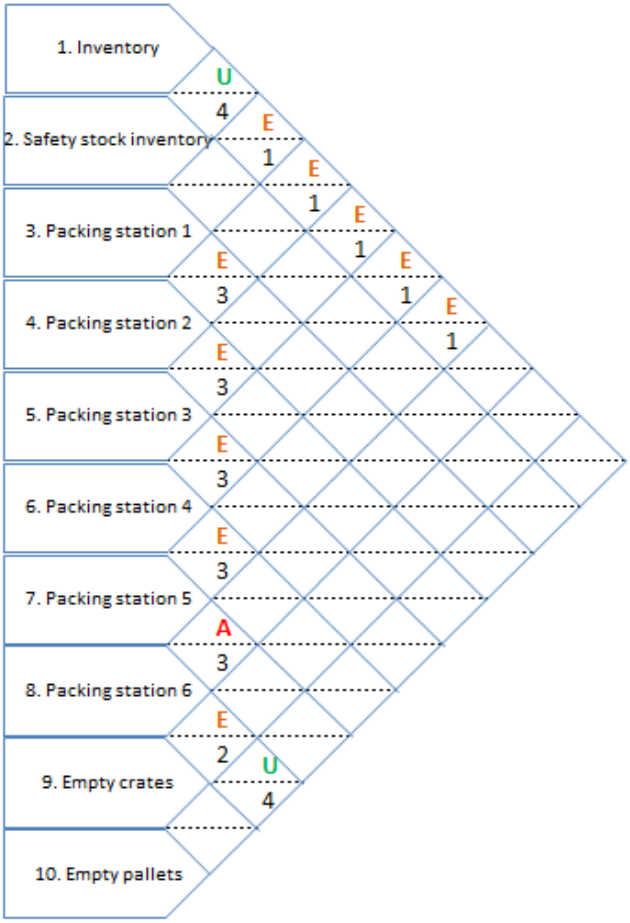


Figure 21: Activity relationship chart

Table 4: Closeness rating

Value	Closeness	Key		Reason
A	Absolutely necessary		1.	Input/ similar input
E	Especially important		2.	Share labour
U	Unimportant		3.	Sequence of workflow
X	Not desirable		4.	Ease of transportation

Having used the activity relationship chart, an activity relationship diagram was created. The diagram in Figure 22 shows the relationship of each activity relative to their current positions with their closeness rating.

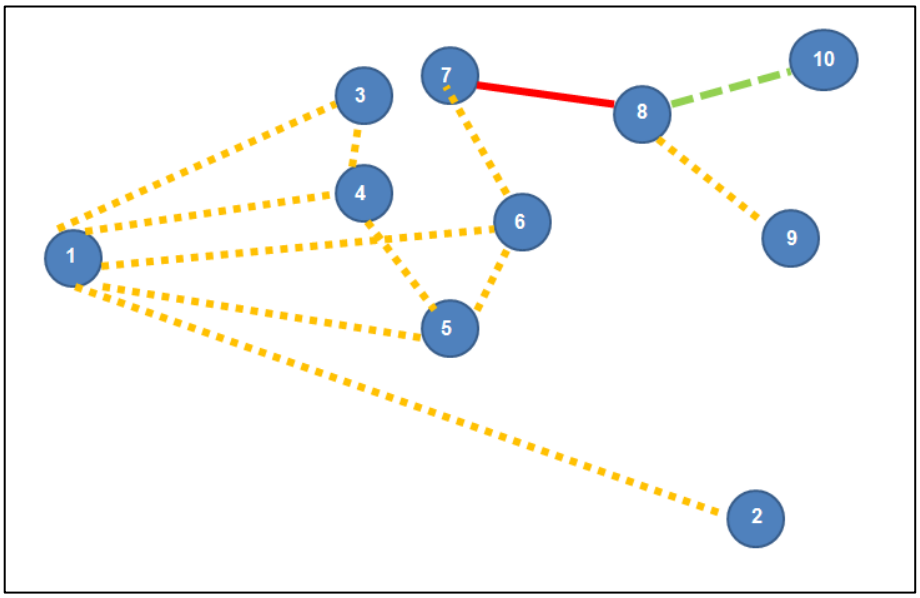


Figure 22: Activity relationship diagram

4.2.2 Space Relationship Diagram

In order to construct the block diagrams and a space relationship diagram, it is necessary to determine the space requirements of each activity. This is done by calculating the total area of the floor space and determining the percentage of floor space each activity occupies. The result of these calculations is shown in Table 5.

Table 5: Space requirements of different activities

	Area (m)	% Occupied Floor space	% Floor space
Inventory	26.00	48.43	19.84
Safety stock inventory	5.20	9.69	3.97
Packing station 1	1.80	3.35	1.37
Packing station 2	1.20	2.24	0.92
Packing station 3	1.20	2.24	0.92
Packing station 4	1.20	2.24	0.92
Packing station 5	1.20	2.24	0.92
Packing station 6	6.09	11.34	4.65
Empty crates	7.20	13.41	5.49
Empty pallets	2.60	4.84	1.98
Total	**53.69**	**100.00**	**40.96**
Total area of floor space	131.07		

Having used the percentage floor space from Table 5 and the activity relationship chart in Figure 21, the following relationship diagram was constructed. The diagram in Figure 23 shows each activity, relating closeness and the floor space it occupies relative to each other.

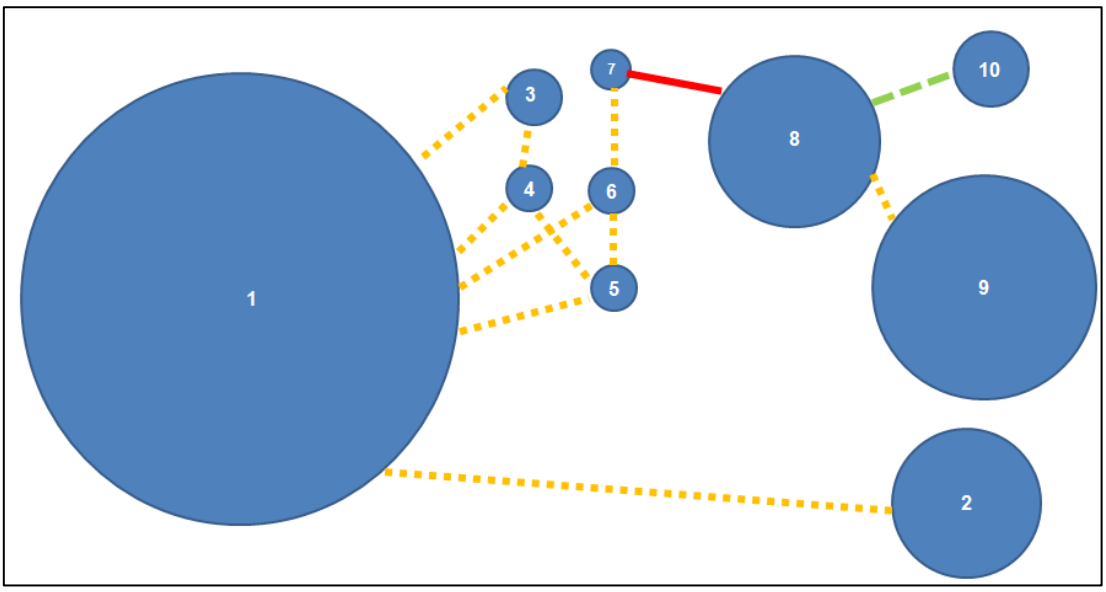


Figure 23: Space relationship diagram

4.2.3 Material Handling:

Material handling at the facility is shown in Table 6 which is derived from the datasets in Appendix C. Once a station has finished packing its part of the hamper, it immediately starts packing the next one. When the average packing time is analysed, it is found that there are bottlenecks at station 1 and 5. From the analysis of the average packing time per unit indicates a clear bottleneck occurs at station 5 where the plastic bag of the hamper is sealed.

Table 6: Material handling of each station

Material handling of each station					
Number	**Description**	**Number of units**	**Average Packing Time* (s)**	**Average Packing time per unit**	**Standard deviation (s)**
1	5 products packed by 1 person:	5	7.90	1.58	2.05
2	2 products packed by 1 person	2	3.08	1.54	1.00
3	2 products packed by 1 person	2	2.32	1.16	0.71
4	2 products packed by 1 person	2	2.90	1.45	0.92
5	Plastic bag is sealed at the bottom with a sealer by 1 person	1	6.96	6.96	1.56
	Total packing time for 1 Hamper	**1**	**14.86**		
6	Pallets are packed	3	8.97	2.99	2.10
	Total number of people = 6				

*The average packing time is calculated using gathered data for each station divided by the number of people working at that station.

The current system is a push system with the major problem being that the total average packing time is slower than the required time in minutes to fulfil the demand. The capacity of the current system is 64.4% of the required capacity as shown in Table 7.

Table 7: Current packing statistics

Current packing time for 1 Hamper (seconds)	**14.48**
Current packing time per pallet (Minutes)	18.94
Required time per pallet (Minutes)	12
Current capacity: (Pallets per day)	29
Required capacity: (Pallets per day)	45

The bottlenecks can be addressed by adding more people to the bottleneck stations. Adding more people to both station 1 and 5 will reduce the packing time. In Table 8 and 9, possible improvements to each station are shown which will bring the system to a 126.6% fulfilment of demand.

Table 8: Improved material handling of each station

		Station				
Number	**Description**	**Number of units**	**Persons**	**Average Time (s)**	**Average time per unit**	**Standard deviation (s)**
1	5 products packed	5	3	2.63	0.53	2.05
2	2 products packed	2	2	1.54	0.77	1.00
3	2 products packed	2	2	1.16	0.58	0.71
4	2 products packed	2	2	1.45	0.73	0.92
5	Plastic bag is sealed at the bottom with sealers. (Max of 2)	1	2	3.48	3.48	1.56
	Total packing time for 1 Hamper			**7.56**		
6	Pallets are packed	3	1	8.97	2.99	2.10
	Total number of people		**12**			

The company has access to two sealers no additional equipment cost will be incurred.

Table 9: Improved packing statistics

Improved packing time for 1 Hamper (seconds)	**7.56**
Improved packing time per pallet (Minutes)	9.45
Required time per pallet (Minutes)	12
Improved capacity: (Pallets per day)	57
Required capacity: (Pallets per day)	45
% fulfilment of required demand	126.6

Fulfilling the required demand is not the only impact the new improvements will have. These improvements require six more people to work at the facility. These additions can be costly. As the work is considered to be unskilled labour, temporary workers can be hired during

peak demand times. When the demand fluctuates, the total number of people per station should be altered accordingly to ensure minimum costs. Different types of hampers consists of different quantities of products (as seen in Table 1: Bill of materials) which must also be taken into consideration. Two sealers are available to the company thus the company will incur no additional equipment cost.

An observation that was made regarding the current facility was wastages due to inventory arriving in sealed boxes; every box must be opened, emptied and folded. These wastages are a problem regardless of the fulfilment of the demand. As the inventory can only arrive in boxes, a way to dispose of the boxes must be explored. A possible solution to this is a recycling baler. The baler receives empty cardboard boxes and compresses them into easily manageable and compact bales of cardboard. Employing the baler will require less labour, but will incur installation cost, maintenance cost and training for employees to use it. A suitability study and a risk assessment will also have to be conducted for the baler. The cost of the baler was considered and both the supplier and the company decided that it will be more environmentally friendly if all products used in hampers were stored in reusable crates.

The crates will entail that a higher number of products can be stacked on a pallet. This change will greatly affect the procedures as the order quantity is larger, but the advantages outweigh the disadvantages as reducing the boxes will mean a tidier work environment, less labour waste and a more environmentally freindly approach. Until all inventories are supplied in crates, boxes will be disposed in the same fashion as always.

4.3 Alternative Facility Layouts

Having used the space requirements and the activity relationship diagram, Figure 24 was constructed. The activities only use 40 percent of the floor space. The other 60% is used for the transportation of pallets with a manual jack. Figure 25 shows a graphic version of the block diagrams.

Option 1 description:

Option 1 is an easily implementable solution as it requires no structural changes to the facility, but allows for the bottlenecks to be removed. The safety hazard of the slope is still present. The following changes were made:

- Pallets containing inventory were reduced to 24 as the total number of product types is 19
- Rows of pallets containing inventory were changed to ensure that 14 pallets can be directly accessed with a manual pallet jack. This change guarantees that inventory levels can be replenished faster
- The packing stations are double and placed in a straight line for optimum efficiency;
- Packing stations have no fixed furniture and can thus be easily reduced when demand fluctuates
- Stations flow chronologically
- Number of packing stations: six
- Number of packers: 12.

1			1	1		1
1			1	1		1
1			1	1		1
1			1	1		1
1			1	1		1
		3	4	5	6	7
				8	8	8
					8	8
						10
		2			9	10
		2			9	
		2			9	9
		2			9	

Figure 24: Alternative block diagram 1

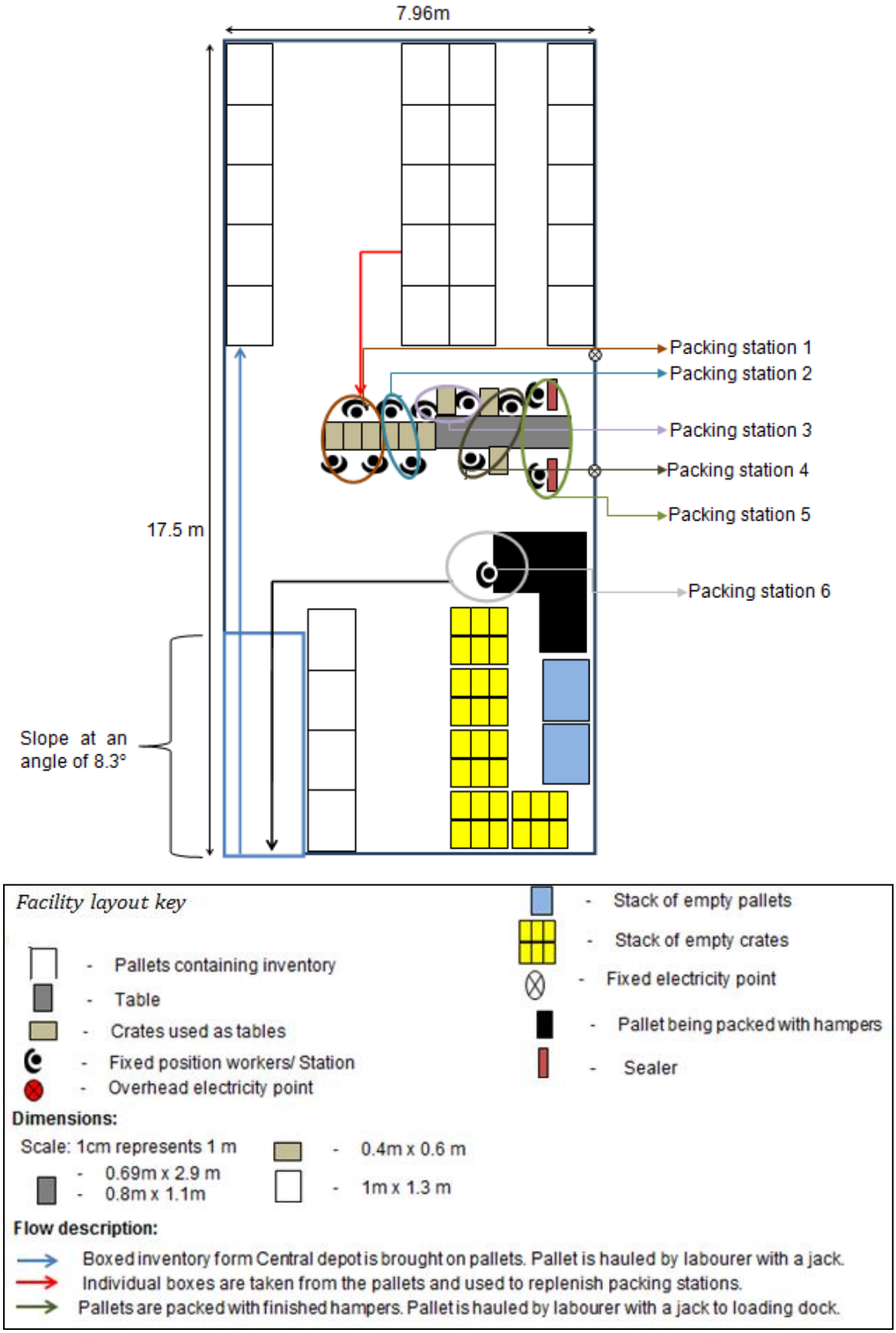


Figure 25: Graphic alternative layout 1.

Option 2 description:

Option 2 will be more difficult to implement and require the facility to temporarily relocate to implement structural changes. Figure 26 showcases the constructed block diagram of alternative 2, while Figure 27 is the graphic version.

The following changes were made:

- Pallets containing inventory are 28, but 14 are directly accessible. High demand, high weight products will be stacked at these 14 positions as they will have to be replenished more often
- Each row of pallets will receive a construction that will allow two inventory loaded pallets to be stacked onto each other. This structure will be similar to that currently at dispatch. This will however require a forklift and forklift operator
- The packing stations are doubled for optimum efficiency
- Packing stations are have no fixed furniture and can thus be easily reduced when demand fluctuates
- The slope is removed and replaced by an open platform lift
- Overhead electric points are added to rotate the work stations and to ensure easier flow from the sealers to the last station
- Stations flow chronologically
- Number of packing stations: six
- Number of packers: 12
- Safety stock is removed from facility as order cycles are reduced to implement JIT principles.

1						1
1						1
1						1
1		3	3	3		1
1				4	4	1
1				5	5	
1				6	6	
1				7	7	
1				8	8	8
					8	8
						10
					9	10
				9	9	9
					9	

Figure 26: Alternative block diagram 2

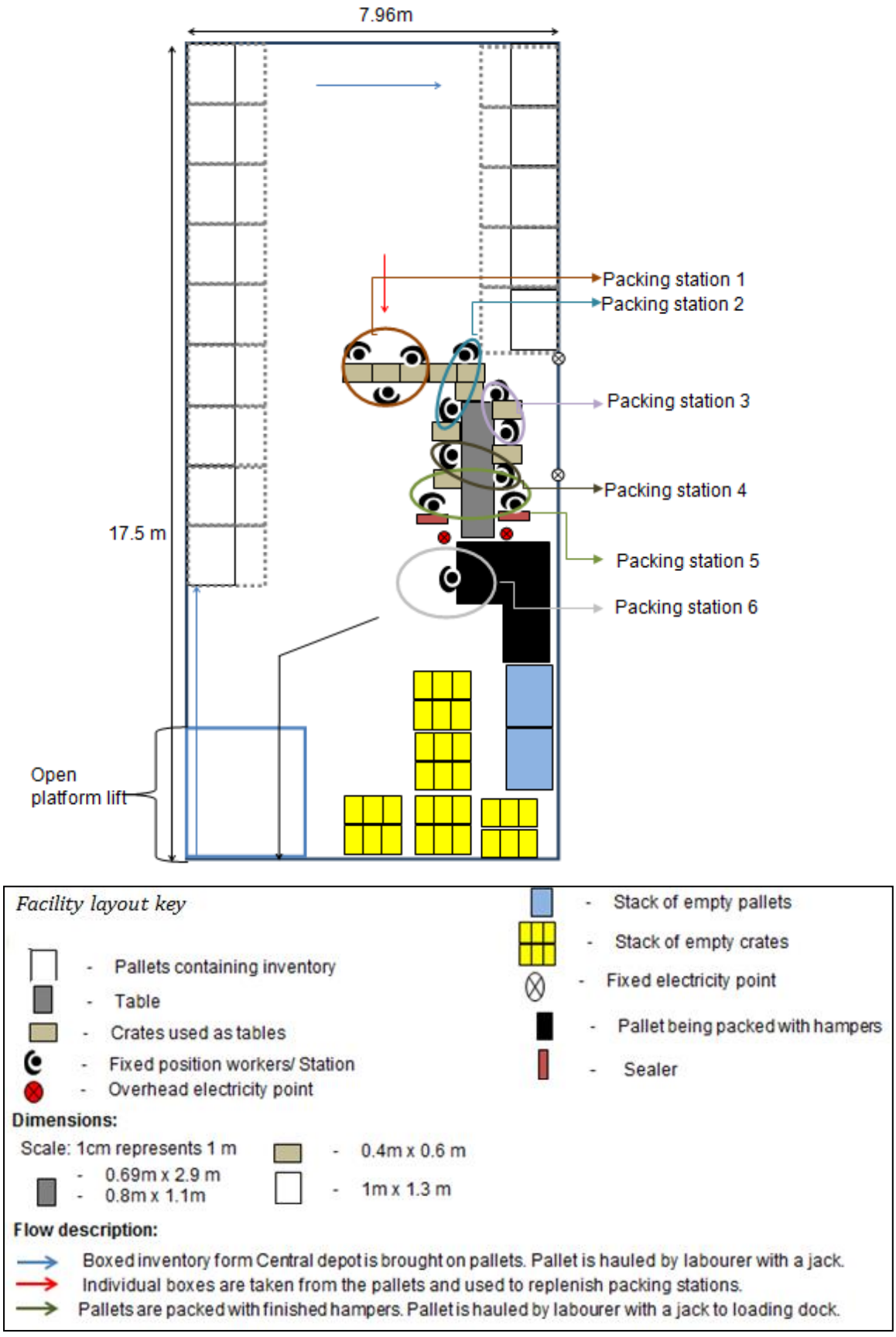


Figure 27: Graphic alternative layout 2.

Option 3 description:

Option 3 is an easily implementable solution as it requires no structural changes to the facility, but allows for the bottlenecks to be removed. Figure 28 showcases the constructed block diagram of alternative 3, while Figure 29 is the graphic version.

Inventory will be stored in fixed places using the Kanban principle (visual storage method):

- It will be easier to see which product types need to be topped up
- Better inventory management as it will ensure that inventory can be visually managed: No more than one pallet for each product type – avoid doubles
- Facility is tidier.

The safety hazard associated with the slope is still present.

The following changes were made:

- There are 20 pallets containing inventory, all are directly accessible. High demand, high mass products will be stacked closest to the door as they will have to be replenished more often
- The packing stations are doubled for optimum efficiency
- Packing stations have no fixed furniture and can thus be easily reduced when demand fluctuates
- Overhead electric points are added to rotate the work stations and to ensure easier flow from the sealers to the last station
- Stations flow chronologically
- Packing stations flow is linear
- Overall flow of materials is circular
- Number of packing stations: six
- Number of packers: 12
- Safety stock is removed as order cycles are reduced to implement JIT principles.

1		1	1	1	1	
1						1
1			3			1
1			3	3		1
1			4	4		1
1			5	5		1
1			6	6		1
1			7	7		
1			8	8		
						10
					9	10
					9	
					9	9
					9	

Figure 28: Alternative block diagram 3

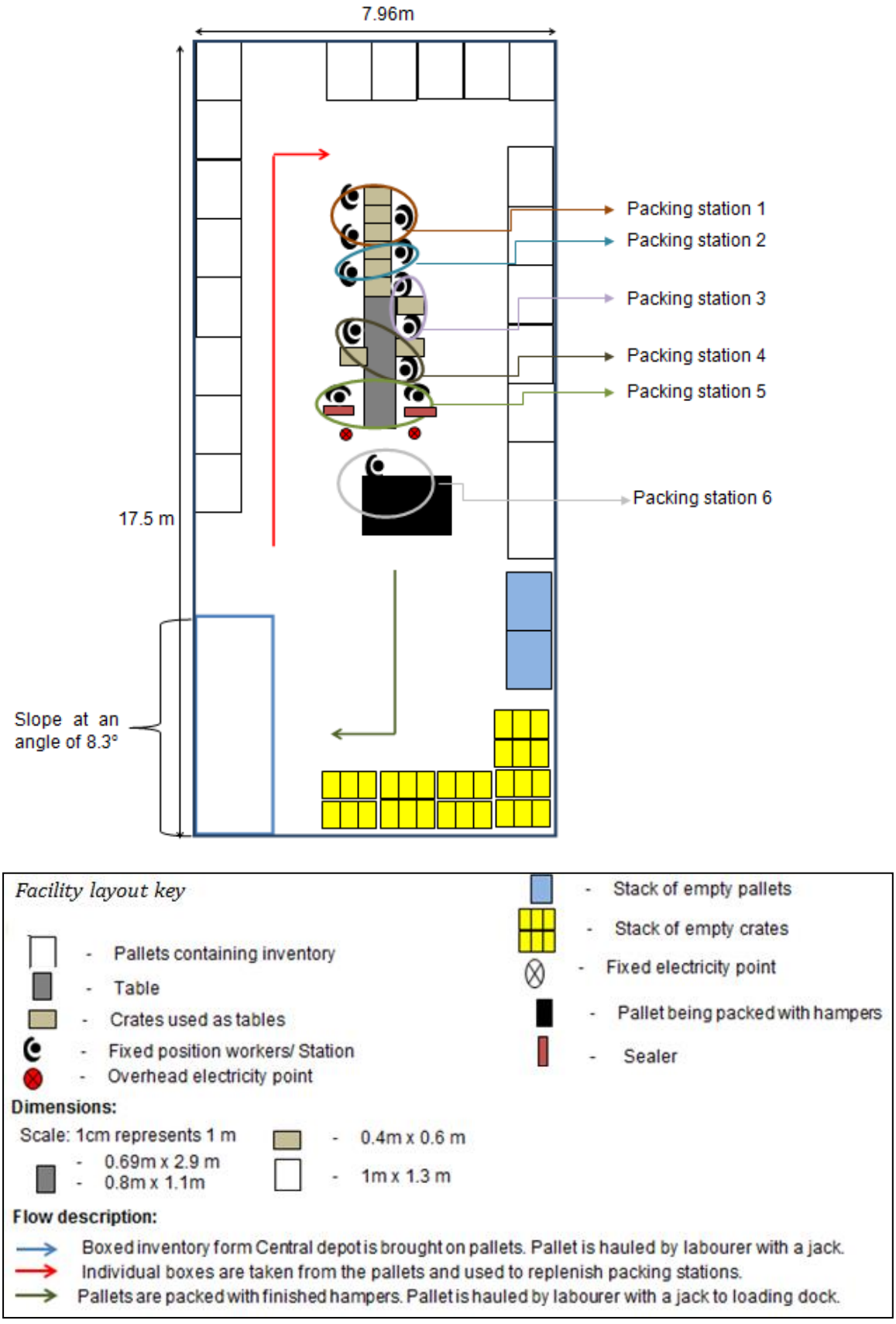


Figure 29: Graphic alternative layout 3.

Option 4 description:

Option 4 will be more difficult to implement and require the facility to relocate temporarily to implement structural changes. Figure 30 showcases the constructed block diagram of alternative 4, while Figure 31 is the graphic version

Inventory will be stored in fixed places using the Kanban principle:

- It will be easier to see which product types need to be topped up
- Better inventory management as it will ensure that inventory can be visually managed: No more than one pallet for each product type – avoid doubles
- Facility is tidier

The following changes were made:

- There are 20 pallets containing inventory, which are all directly accessible. High demand, high mass products will be stacked closest to the door as they will have to be replenished more often
- The packing stations are double for optimum efficiency
- Packing stations have no fixed furniture and can thus be easily reduced when demand fluctuates
- The slope is removed and replaced by an open platform lift
- Overhead electric points are added to rotate the work stations and to ensure easier flow from the sealers to the last station
- Stations flow chronologically
- Circular flow of materials
- Number of packing stations: six
- Number of packers: 12
- Safety stock is removed as order cycles are reduced to implement JIT principles.

1		1	1	1	1	
1						1
1			3			1
1			3	3		1
1			4	4		1
1			5	5		
1			6	6		
1			7	7		
1			8	8		
1						10
1						10
					9	
					9	9
					9	

Figure 30: Alternative block diagram 4

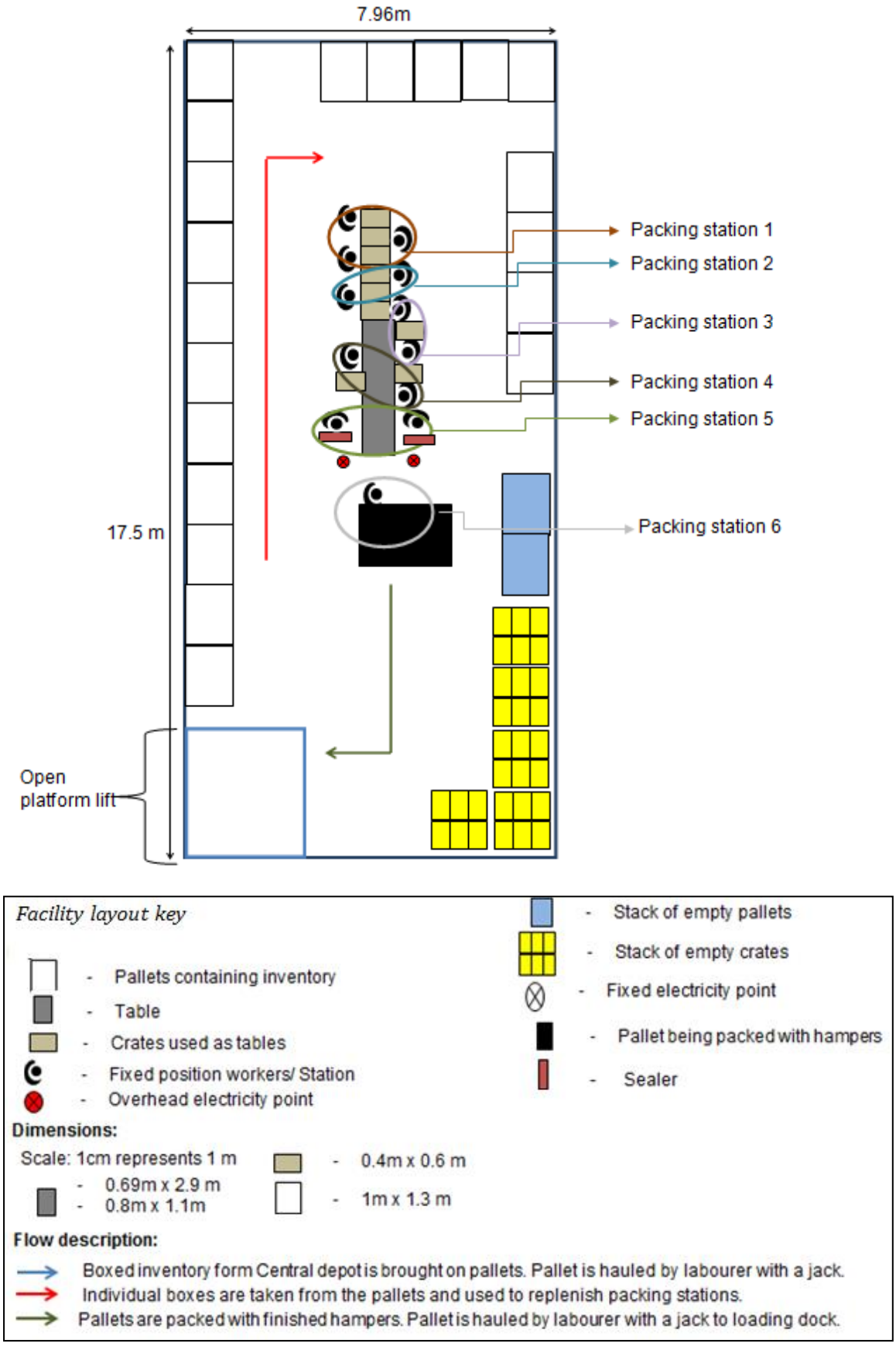


Figure 31: Graphic alternative layout 4.

4.4 Evaluation of Alternatives:

Three methods were used to evaluate the alternatives. Firstly the advantages and disadvantages of each alternative were listed, then factors was used to rank alternatives and lastly the weighted factor comparison method was used.

Comparing advantages and disadvantages

Each alternative is scrutinized based on its description. Every element in the facility is analysed and either described as an advantage or a disadvantage. The total number of advantages and disadvantages are calculated and the alternatives are ranked in Table 10.

Table 10: Advantages and disadvantages for each alternative layout

	Advantages	Disadvantages
Alternative 1:	• Inventory carrying pallets were reduced • 14 pallets are directly accessible • Packing station operators are doubled • Initial setup time is low	• Slope is still a safety hazard • Overall flow is non circular. • Packing station flow is non-linear. • Facility still too crowded. • Safety stock still present • Electrical point restriction • No JIT tools used
Total:	4	7
Alternative 2:	• Inventory carrying pallets are reduced • 14 pallets are directly accessible • Safety hazard is removed • Flow of material is more circular • Facility is less crowded • Packing station operators are doubled • Overhead electrical points • Reduced safety stock as implementation of JIT	• Height restriction • Forklift operator required • Forklift required • Temporarily relocation • Costly • Non-linear flow of material • Safety stock still present • Electrical point restriction • Initial setup time is high • Start-up time is high
Total:	8	12
Alternative 3:	• Facility is less crowded • Packing station operators are doubled • Overhead electrical	• Safety hazard still present • Initial setup time is high

		points are added and relocated • Overall flow is circular • Inventory carrying pallets were reduced • 20 pallets are directly accessible • Workstation flow is linear • Reduced safety stock as implementation of JIT	
	Total:	8	2
Alternative 4:		• Safety hazard is removed • Overall flow is circular • Workstation flow is linear • Packing station operators are doubled • Reduced safety stock as implementation of JIT • Facility is less crowded • Overhead electrical points are added and relocated • Inventory carrying pallets were reduced • 20 pallets are directly accessible	• Temporarily relocation • Initial setup time is high
	Total:	9	2

Analysis of Table 10 shows that option three and four are more viable than options 1 and 2 due to the fact that their advantages greatly outweigh their disadvantages. Their advantages are also considerably more than that of option one and two. Using this comparison method, alternative 3 and 4 are recommended.

Ranking:

Each alternative is ranked based on the ability of the factor to meet the requirements set for that factor as shown in Table 11. A factor is considered to meet the requirements if it meets that requirement. If it exceeds the requirements it is assigned a higher ranking and if the factor fails it is assigned a lower ranking.

Table 11: Ranking of factors of each alternative layout

	Ranking			
	Alternative 1	**Alternative 2**	**Alternative 3**	**Alternative 4**
Criteria:				
1. Facility tidiness	Fails to meet requirements	Meets requirements	Exceeds requirements	Exceeds requirements
2. Easily accessible inventory	Meets requirements	Meets requirements	Exceeds requirements	Exceeds requirements
3. Electrical points	Fails to meet requirements	Meets requirements	Exceeds requirements	Exceeds requirements
4. Overall flow	Fails to meet requirements	Meets requirements	Exceeds requirements	Exceeds requirements
5. Workstation flow	Meets requirements	Fails to meet requirements	Meets requirements	Meets requirements
6. Safety hazard	Fails to meet requirements	Meets requirements	Fails to meet requirements	Meets requirements
7. Safety Stock presence	Fails to meet requirements	Fails to meet requirements	Meets requirements	Meets requirements
8. Number of packing stations	Meets requirements	Meets requirements	Meets requirements	Meets requirements
9. Sensitivity to change	Meets requirements	Meets requirements	Meets requirements	Meets requirements
10. Flexibility	Meets requirements	Meets requirements	Meets requirements	Meets requirements
11. Space utilization	Meets requirements	Meets requirements	Exceeds requirements	Exceeds requirements
12. Ease of supervision and control	Fails to meet requirements	Meets requirements	Meets requirements	Meets requirements
13. Time required to get into operation	Fails to meet requirements	Fails to meet requirements	Meets requirements	Meets requirements
14. Cost implications	Exceeds requirements	Fails to meet requirements	Meets requirements	Fails to meet requirements
15. Height restriction	Meets requirements	Fails to meet requirements	Meets requirements	Meets requirements
16. Ease of initial start-up	Exceeds requirements	Fails to meet requirements	Meets requirements	Fails to meet requirements

The rankings in Table 11 were calculated for each alternative. Shown in Table 12 is the score of the rankings. Alternative 1 fails the most requirements, alternative 2 and 3 meets most requirements and both alternative 3 and 4 exceed requirements most.

Table 12: Score of the ranking

	Ranking			
	Alternative 1	**Alternative 2**	**Alternative 3**	**Alternative 4**
Criteria:				
Fails to meet requirements	7	6	1	2
Meets requirements	7	10	10	9
Exceeds requirements	2	0	5	5

Using this comparison method only alternatives 3 and 4 are recommended.

Weighted factor comparison method:

Weighted factor comparison uses the same factors as in the ranking comparison, but now each factor is weighted and numerically rated. If the factor failed to meet requirements it was rated as 1. If the factor met requirements it was rated as 2. If the factor exceeded requirements it was rated as 3. The rate (Rt) multiplied with the weight (Wt) gave the score (Sc). The alternative with the highest score in Table 13 will be recommended.

Table 13: Weighted factor comparison

Factor	Wt	Alternative 1		Alternative 2		Alternative 3		Alternative 4	
		Rt	Sc	Rt	Sc	Rt	Sc	Rt	Sc
1. Facility tidiness	1	1	1	2	2	3	3	3	3
2. Easily accessible inventory	5	2	10	2	10	3	15	3	15
3. Electrical points	10	1	10	2	20	3	30	3	30
4. Overall flow	10	1	10	2	20	3	30	3	30
5. Workstation flow	10	2	20	1	10	2	20	2	20
6. Safety hazard	10	1	10	2	20	1	10	2	20
7. Safety Stock presence	1	1	1	1	1	2	2	2	2
8. Number of packing stations	10	2	20	2	20	2	20	2	20
9. Sensitivity to change	5	2	10	2	10	2	10	2	10
10. Flexibility	5	2	10	2	10	2	10	2	10
11. Space utilization	5	2	10	2	10	3	15	3	15
12. Ease of supervision and control	1	1	1	2	2	2	2	2	2
13. Time required to get into operation	10	1	10	1	10	2	20	2	20
14. Cost implications	10	2	20	2	20	2	20	1	10
15. Height restriction	10	2	20	1	10	2	20	2	20
16. Ease of initial start-up	5	3	15	1	5	2	10	1	5
Total:			178		180		237		232

The recommendation according to the weighted factor comparison is either alternative 3 or alternative 4 as they have the highest scores.

All three methods state that alternative 3 is the best option.

4.5 Recommendation:

After careful consideration of all aspects concerning the facility the following recommendation was made:

Employee ownership:

- Each employee must be assessed according to Maslow's hierarchy in Figure 8
- Management style must change to a leadership style to incorporate a culture of accountability as described in Section 2
- Importance of these changes: Increases productivity

Doubling packing stations in hamper room:

- Packing stations one to five must request more people as described in Table 8. This will greatly improve the productivity as demand fulfilment increased as seen in Table 9
- When demand fluctuates packing stations can easily be reduced as packing stations are have no fixed furniture

Order replenishment:

- Implementation of the order replenishment schedule is highly recommended as it will allow the facility to move towards a JIT procurement plan
- The order replenishment schedule is less time consuming and more accurate than current methods
- The new system will allow for proper record keeping

New facility layout:

- Evaluation of the alternatives revealed that alternative 3 and 4 are adjacent in their appeal for the situation. Alternative 3 will be less costly than alternative 4, but to reduce the safety hazard and potential future injuries, it is recommended that alternative 4 is implemented
- Once an alternative has been implemented it will be the responsibility of management that the facility will improve on a continuous basis and not regress to old ways
- Stocking of inventory loaded pallets must happen in a circular pattern with ranking number 1 closest to the door and ranking number 21 furthest from the door. Ranking of stock can be found in Table 14. These products are ranked in terms of high weight, highly utilized products that will need replenishment faster. The final layout with the rankings can be seen in Figure 32

Section 5 will validate and verify the final recommended solution.

Table 14: Stock order ranking

Ranking	Code:	Product:	Weight: (Kg)	Number of products in a pallet	Overall Product Utilization (%)	Utilization x Weight
1	41-0005-	Ent French Polony 1Kg	1	900	75	67500
2	41-0036-	Ent Spec Garlic Polony 500g	0.5	1680	50	42000
3	41-2203-	Ent Hamper Skinless Franks 50x375g	0.375	1750	50	32812.5
4	41-2204-	Ent Hamper Smoked Russians 50x357g	0.375	1750	50	32812.5
5	41-0853-	Ent Ham & Cheese Roll 500g	0.5	1260	50	31500
6	41-2137-	Ren Smoked Bacon Spread 125g	0.125	5000	50	31250
7	41-4092-	Ren Liver Spread 250g	0.25	2400	50	30000
8	41-3466-	Ren Smoked Bacon Spread 125g	0.125	4760	50	29750
9	41-2140-	Ren Liver Spread 250g	0.25	2250	50	28125
10	41-0687-	Mielie-kip Chic Viennas 500g	0.5	1848	25	23100
11	41-0688-	Mielie-kip Chic Polony 1Kg	1	900	25	22500
12	41-2188-	Ent Premium French Polony 1Kg	1	900	25	22500
13	41-0120-	Ent Smoked Viennas 1Kg	1	756	25	18900
14	41-0118-	Ent Red Viennas 1 Kg	1	756	25	18900
15	41-2189-	Ent Premium Chick Viennas 1 Kg	1	756	25	18900
16	41-1880-	Ent Chicken & Cheese Roll 500g	0.5	1440	25	18000
17	41-0682-	Mielie-kip Chic Polony 5x250g	0.25	2800	25	17500
18	41-0852-	Ent Chopped Ham Mini Roll 500g	0.5	1260	25	15750
19	41-0735-	Ent Ham & Tongue Roll 500g	0.5	1260	25	15750
20	41-0685-	Mielie-kip Chic Viennas 1Kg	1	630	25	15750
21	41-2202-	Ent Premium Snack Pack	0.4	1040	25	10400

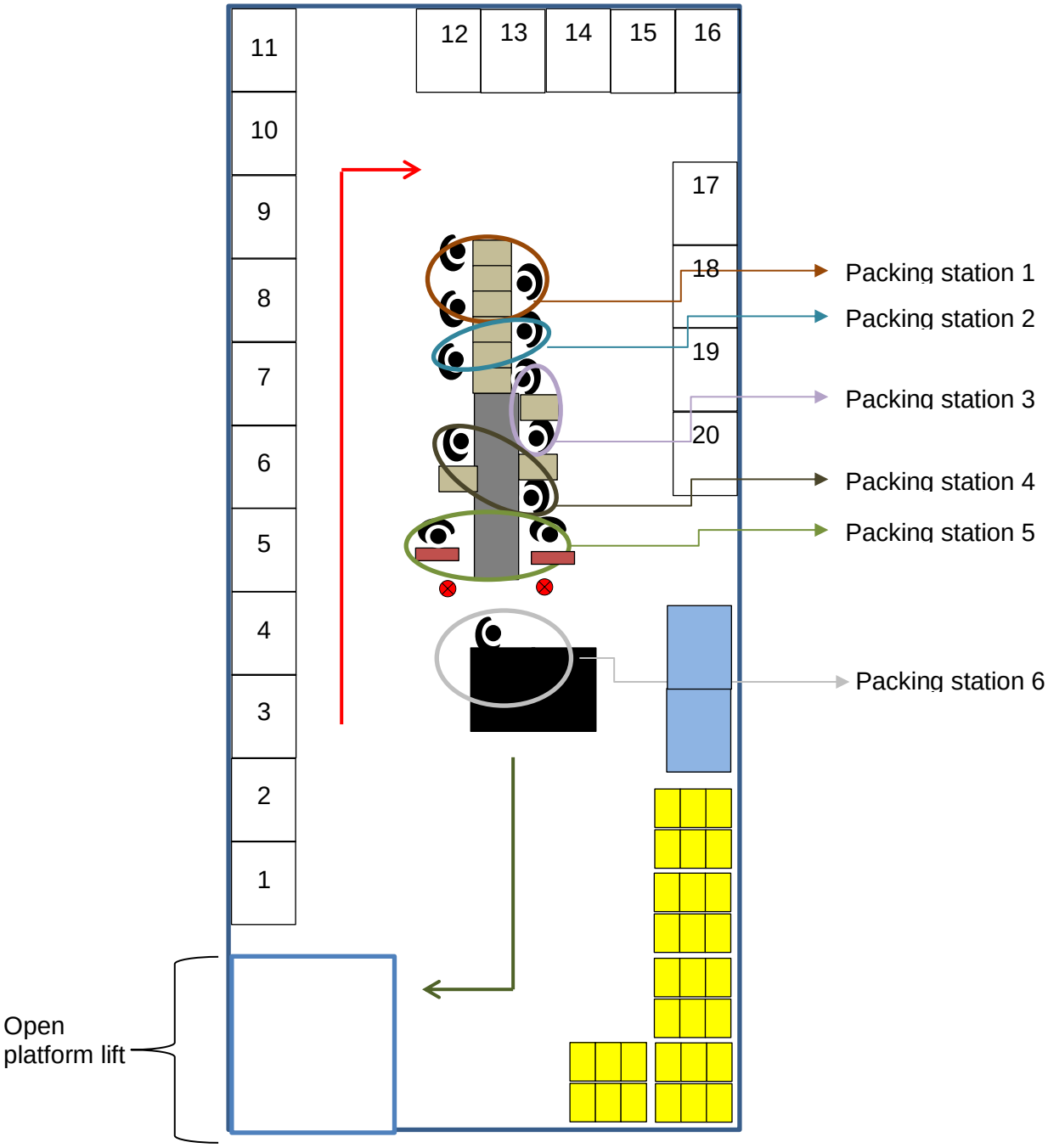


Figure 32: Final layout

5. VERIFICATION AND VALIDATION

5.1 Order Replenishment Schedule:

Verification: Data used in the order replenishment schedule spreadsheet was verified by doing black box testing. The test was not concerned with the software code or how processing takes place, but rather the expected output that resulted from a given input. The black box testing was done via entering a mock order with a predetermined number of inventory on hand. The same calculation was done manually. The data was considered verified once the manual calculation and the data form the spreadsheet matched.

Validation: The order replenishment schedule would be deemed validated if it fulfils the requirements of customer. In this case, management is the customer. Upon discussion with management the spreadsheet met the requirements as it was less time consuming than manual calculations, there was a smaller chance for calculating error and it was in a format already known to them. The spreadsheet replaced loose papers and improved record keeping.

5.2 Layout Design:

Verification: Verification was done by ensuring that each activity was taken into account, that each activity had sufficient space and that every element of each activity was considered when planning the alternative layouts.

Validation: In order to validate changes to the facility, time studies will be conducted the facility once the new layout has been implemented. The data will be analysed and processed.

All the project objectives have been addressed to the satisfaction of management as they have chosen to implement the recommended facility layout. The recommended facility will allow the facility to function in such a way that the demand can be fulfilled if the parameters stay the same. It is important to address possible sensitivity issues that may come to rise if the input parameters of the facility change.

5.3 Sensitivity Analysis:

A sensitivity analysis is a method of determining how the facility would react to change and whether it will be able to function if certain changes occur. As already stated demand will fluctuate at certain times. The facility must be able to adapt to accommodate these changes. As the packing stations are not fixed furniture, they can be reduced to suit the demand better without disrupting the way the facility operates. The same can be said for the position of inventory. The place holders for inventory loaded pallets are not fixed and can be reduced if the demand lessens. It will also be able to accommodate changes in the hamper. If a product type is removed and replaced with another product type, inventory can still be stored in the same way.

When considering the sensitivity of the order replenishment schedule spreadsheet, there is more of a problem. If the inventory on hand is not correctly calculated or entered, there might be a stock out or too much stock. If the incorrect cycle for ordering is selected, inventory levels will be wrong and there might be a problem with stock levels. With careful actions this should not be a problem.

The sensitivity of the recommended alternative was assessed through analysing the cost of lost sales for different input parameters. The input parameters assessed were changes in

demand and changes in labour force. For simplification purposes the cost of lost sales was determined as the average between the maximum and minimum stated in Section 1.3

Table 15: Average cost of lost sales

Average cost of lost sales	R121,875.00	Per 13 pallets
	R9,375.00	Per pallet
	R125.00	Per Hamper

Current packing capacity for recommended facility: 57 pallets as shown in Table 9.The packing ability of a single packing operator was calculated as 4.75 pallets per day. These calculations together with Table 15 are used to determine the impact of a changing demand and the impact of changing the number of operators in terms of cost of lost sales as seen in Table 16.

Table 16: Change in cost of lost sales as inputs change

Demand (Number of pallets)	Cost of lost sales	Number of packing station operators	Cost of lost sales
15	-R393,750.00	3	R400,781.25
20	-R346,875.00	5	R311,718.75
30	-R253,125.00	9	R133,593.75
45	-R112,500.00	10	R89,062.50
66	R84,375.00	15	-R133,593.75
80	R215,625.00	16	-R178,125.00

The resulting impact was showcased in Figure 33 and 34.

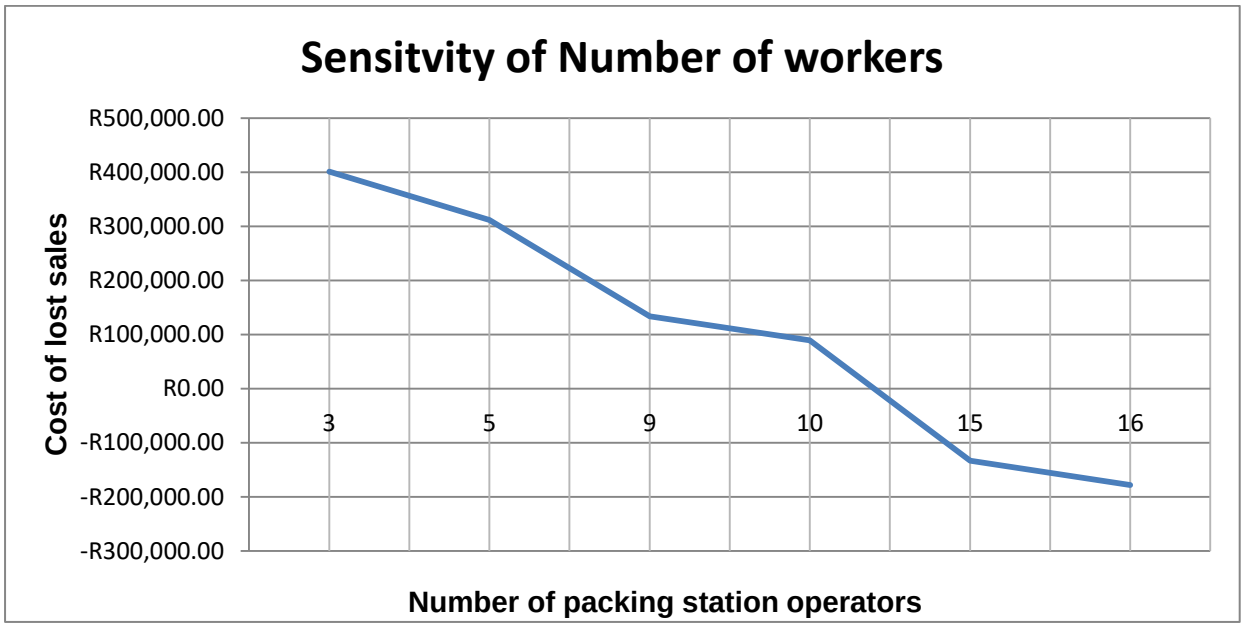


Figure 33: Impact of changed number of operators on cost of lost sales

A change in the number of operators will have a great impact on the cost of lost sales and should be monitored closely.

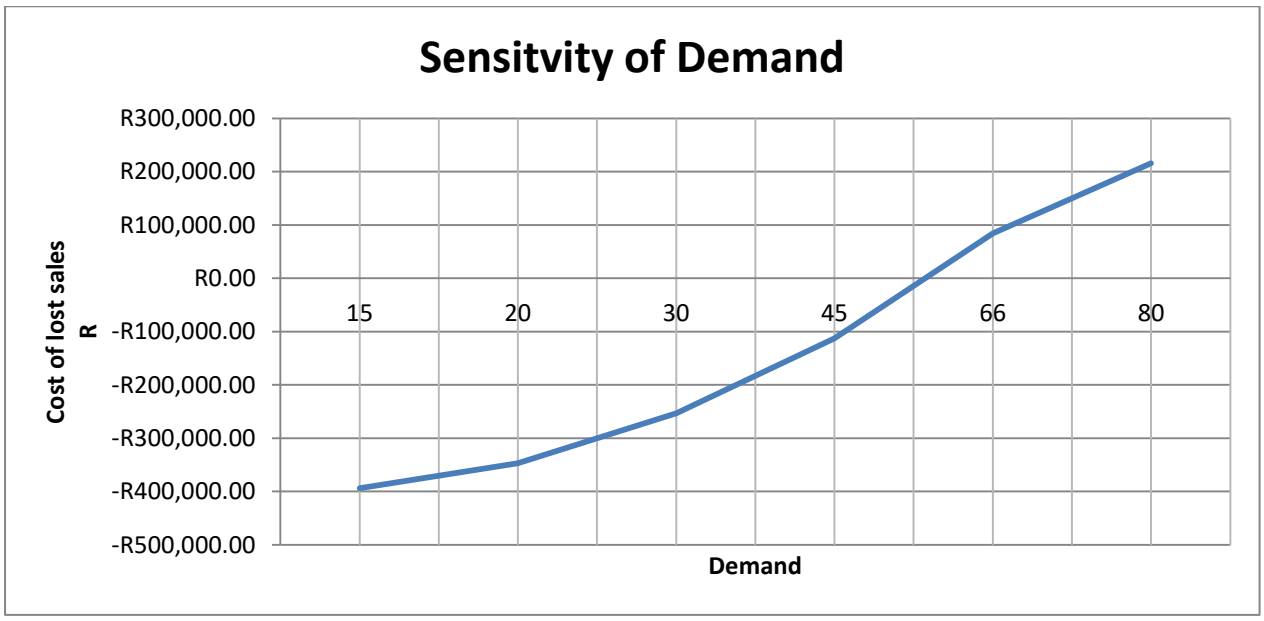


Figure 34: Impact of changing demand on cost of lost sales

A change in demand will have a great impact on the cost of lost sales and should be monitored closely. Section 6 contains the conclusion for this report.

6. CONCLUSION

This document described the problem of underutilized labour at a manual packing line at a meat processing facility and the effect it has on cost of lost sales. The importance of achieving required demands was emphasised and an in depth analysis was done on the facility as it currently operates to determine why the facility is underperforming. Through analysis, time studies and observation of the facility several issues came to light. These issues where discussed and a literature review was done to determine the best practices.

The problem investigation revealed that double the amount of packing stations (including the sealer) will allow for the fulfilment of the demand. The change in stations can easily be facilitated without changing the structure of the facility and the change can happen timeously if alternative 1 is implemented. In alternative 2, the safety hazard of the slope is removed.

Management opted to implement alternative 3 for the time being until financially it becomes an option to implement alternative 4.

Impact of change:

The changes from the current facility to alternative 3 will have many impacts. The facility will be less crowded, workstations will have a linear flow, workstations will have double the number of operators, the overall facility will have a circular flow and overhead electrical points will be added.

Implementation of the recommendation will have the following impacts:

The identification of employees on the Maslow hierarchy will allow management to personalise their plan to change the culture of the company. The new culture and change in leadership will assure that employees are highly engaged and that their goals are fully aligned with those of the company. Once employee ownership and accountability rises productivity will rise and this will be good for morale.

By implementing the recommendations for doubling the packing stations, there is a higher possibility for demand fulfilment. This will lead to lower cost of lost sales. A more productive team will receive more recognition from management and will further improve employee ownership.

Implementation of the new facility layout will allow the facility to run more smoothly and at a higher productivity rate. The tidier facility will be easier to manage and take pride in. The new facility layout will enable management to utilize labour optimally.

Application of the order replenishment schedule will be less time consuming than the previous manual method and it will allow for proper record keeping. The record keeping can be used in future to identify certain issues that may arise.

Overall the new leadership style, the new facility layout and the new order replenishment schedule will greatly improve productivity, effectiveness, labour utilization and company morale.

Implementation of all of the above will ensure that the unfilled demand of 13 pallets per day is fulfilled. This fulfilment will decrease the cost of lost sales that amounted to R175 500-00 per day.

Future work:

For future work, the ramp discussed in alternative 4 and 2 can be investigated and analysed in terms of feasibility and the necessity there of. Implementation of the ramp will enhance the new layout and material flow. For future investigation, the variability in products can be reduced to streamline the process. Another possible future project might be the addition of a freezer and outside entrance for deliveries for sole use of the hamper room.

As discussed in Section 4.2.3, inventory can be stored and transported in crates to reduce the wastes associated with the boxes in which inventory was currently packed.

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8. APPENDICES

Appendix A: Industry Sponsorship form

Department of Industrial & Systems Engineering
Final Year Projects
Identification and Responsibility of Project Sponsors

All Final Year Projects are published by the University of Pretoria on *UP Space* and thus freely available on the Internet. These publications portray the quality of education at the University and have the potential of exposing sensitive company information. It is important that both students and company representatives or sponsors are aware of such implications.

Key responsibilities of Project Sponsors:

A project sponsor is the key contact person within the company. This person should thus be able to provide the best guidance to the student on the project. The sponsor is also very likely to gain from the success of the project. The project sponsor has the following important responsibilities:

1. Confirm his/her role as project sponsor, duly authorised by the company. Multiple sponsors can be appointed, but this is not advised. The duly completed form will considered as acceptance of sponsor role.
2. 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 from the company's perspective.
3. Review the Final Project Report (delivered during the second semester), ensuring that information is accurate and that the solution addresses the problems and/or design requirements of the defined project.
4. Acknowledges the intended publication of the Project Report on UP Space.
5. Ensures that any sensitive, confidential information or intellectual property of the company is not disclosed in the Final Project Report.

Project Sponsor Details:

Company:	**Enterprise Foods**
Project Description:	**Facilities planning and supply chain management analysis for the Hamper Room at Enterprise Foods**
Student Name:	**Anna FS Keeve**
Student number:	**13005805**
Student Signature:	
Sponsor Name:	**S. Mdledle**
Designation:	**Ham Factory Manager**
E-mail:	**simphiwe.mdledle@tigerbrands.com**
Tel No:	**011 821 7077**
Cell No:	**079 554 3710**
Fax No:	**086 293 4945**
Sponsor Signature:	

Appendix B: Screenshot from Order Replenishment Schedule

Manual inventory stock sheet

STOCK SHEET: Hamper Room

DATE: _____

CODE	PRODUCT NAME	NUMBER OF BOXES	UNITS PER BOX
5	ENT FRENCH POLONY 1 KG		
12	ENT FRENCH POLONY 500 G		
36	ENT SP GARLIC 500 G		
852	ENT CHOP HAM ROLL 500 G		
118	ENT VIENNAS RED 1 KG		
120	ENT VIENNAS SMOKED 1 KG		
129	ENT VIENNAS 500 G		
130	ENT VIENNAS 500 G		
685	MIELIE CHICK VIENNAS 1 KG		
688	MIELIE CHICK POLONY 1 KG		
733	BACON & EGG ROLL 500 G		
735	HAM & TONGUE ROLL 500 G		
3274	REN CHICK SPREAD 125 G		
4091	REN LIVER SPREAD 125 G		
2140	REN LIVER SPREAD 250 G		
4092	REN LIVER SPREAD 250 G		
2203	FRANKFURTERS 375 G		
158	FRANKFURTERS 375 G		
2204	ENT SMOKE RUSSIANS 375 G		
421	ENT SMOKE RUSSIANS 375 G		
430	ENT SMOKE RUSSIANS 500 G		
853	ENT HAM & CHEESE ROLL 500 G		
1880	ENT CHICKEN & CHEESE ROLL 500 G		
2202	ENT CHICKEN POLONY SNACK PACK		
2188	ENT CHICKEN POLONY 1 KG		
2189	ENT CHICKEN VIENNA 1 KG		
1893	NO PORK POLONY 1KG		
1894	POLONY SPREAD 500 G		
1937	NO PORK POLONY 500 G		
1198	CHICKEN POLONY 500 G		
687	CHICKEN VIENNAS 500 G		
682	MIELIE CHIC POLONY 250 G		
2137	BACON SPREAD 125 G		
3466	BACON SPREAD 125 G		
45380	EASY SLICE CHEESE 400 G		

Excel formulas

Number of pallets
=((Demand!$C$7*75*'Bill of materials'!F4+Demand!$C$8*75*'Bill of materials'!G4+Demand!$C$9*75*'Bill of materials'!H4+Demand!$C$10*75*'Bill of materials'!I4)-(Inventory!L6*'Bill of materials'!D4)) ('Bill of materials'!E4) 'Bill of materials'!
=((Demand!$C$7*75*'Bill of materials'!F5+Demand!$C$8*75*'Bill of materials'!G5+Demand!$C$9*75*'Bill of materials'!H5+Demand!$C$10*75*'Bill of materials'!I5)-(Inventory!L7*'Bill of materials'!D5)) ('Bill of materials'!E5) 'Bill of materials'!
=((Demand!$C$7*75*'Bill of materials'!F6+Demand!$C$8*75*'Bill of materials'!G6+Demand!$C$9*75*'Bill of materials'!H6+Demand!$C$10*75*'Bill of materials'!I6)-(Inventory!L8*'Bill of materials'!D6)) ('Bill of materials'!E6) 'Bill of materials'!
=((Demand!$C$7*75*'Bill of materials'!F7+Demand!$C$8*75*'Bill of materials'!G7+Demand!$C$9*75*'Bill of materials'!H7+Demand!$C$10*75*'Bill of materials'!I7)-(Inventory!L9*'Bill of materials'!D7)) ('Bill of materials'!E7) 'Bill of materials'!
=((Demand!$C$7*75*'Bill of materials'!F8+Demand!$C$8*75*'Bill of materials'!G8+Demand!$C$9*75*'Bill of materials'!H8+Demand!$C$10*75*'Bill of materials'!I8)-(Inventory!L10*'Bill of materials'!D8)) ('Bill of materials'!E8) 'Bill of materials'!
=((Demand!$C$7*75*'Bill of materials'!F9+Demand!$C$8*75*'Bill of materials'!G9+Demand!$C$9*75*'Bill of materials'!H9+Demand!$C$10*75*'Bill of materials'!I9)-(Inventory!L11*'Bill of materials'!D9)) ('Bill of materials'!E9) 'Bill of materials'!
=((Demand!$C$7*75*'Bill of materials'!F10+Demand!$C$8*75*'Bill of materials'!G10+Demand!$C$9*75*'Bill of materials'!H10+Demand!$C$10*75*'Bill of materials'!I10)-(Inventory!L12*'Bill of materials'!D10)) ('Bill of materials'!E10) 'Bill of materials'!
=((Demand!$C$7*75*'Bill of materials'!F11+Demand!$C$8*75*'Bill of materials'!G11+Demand!$C$9*75*'Bill of materials'!H11+Demand!$C$10*75*'Bill of materials'!I11)-(Inventory!L13*'Bill of materials'!D11)) ('Bill of materials'!E11) 'Bill of materials'!
=((Demand!$C$7*75*'Bill of materials'!F12+Demand!$C$8*75*'Bill of materials'!G12+Demand!$C$9*75*'Bill of materials'!H12+Demand!$C$10*75*'Bill of materials'!I12)-(Inventory!L14*'Bill of materials'!D12)) ('Bill of materials'!E12) 'Bill of materials'!
=((Demand!$C$7*75*'Bill of materials'!F13+Demand!$C$8*75*'Bill of materials'!G13+Demand!$C$9*75*'Bill of materials'!H13+Demand!$C$10*75*'Bill of materials'!I13)-(Inventory!L15*'Bill of materials'!D13)) ('Bill of materials'!E13) 'Bill of materials'!
=((Demand!$C$7*75*'Bill of materials'!F14+Demand!$C$8*75*'Bill of materials'!G14+Demand!$C$9*75*'Bill of materials'!H14+Demand!$C$10*75*'Bill of materials'!I14)-(Inventory!L16*'Bill of materials'!D14)) ('Bill of materials'!E14) 'Bill of materials'!
=((Demand!$C$7*75*'Bill of materials'!F15+Demand!$C$8*75*'Bill of materials'!G15+Demand!$C$9*75*'Bill of materials'!H15+Demand!$C$10*75*'Bill of materials'!I15)-(Inventory!L17*'Bill of materials'!D15)) ('Bill of materials'!E15) 'Bill of materials'!
=((Demand!$C$7*75*'Bill of materials'!F16+Demand!$C$8*75*'Bill of materials'!G16+Demand!$C$9*75*'Bill of materials'!H16+Demand!$C$10*75*'Bill of materials'!I16)-(Inventory!L18*'Bill of materials'!D16)) ('Bill of materials'!E16) 'Bill of materials'!
=((Demand!$C$7*75*'Bill of materials'!F17+Demand!$C$8*75*'Bill of materials'!G17+Demand!$C$9*75*'Bill of materials'!H17+Demand!$C$10*75*'Bill

of materials'!I17)-(Inventory!L19*'Bill of materials'!D17)) ('Bill of materials'!E17) 'Bill of materials'!
=((Demand!$C$7*75*'Bill of materials'!F18+Demand!$C$8*75*'Bill of materials'!G18+Demand!$C$9*75*'Bill of materials'!H18+Demand!$C$10*75*'Bill of materials'!I18)-(Inventory!L20*'Bill of materials'!D18)) ('Bill of materials'!E18) 'Bill of materials'!
=((Demand!$C$7*75*'Bill of materials'!F19+Demand!$C$8*75*'Bill of materials'!G19+Demand!$C$9*75*'Bill of materials'!H19+Demand!$C$10*75*'Bill of materials'!I19)-(Inventory!L21*'Bill of materials'!D19)) ('Bill of materials'!E19) 'Bill of materials'!
=((Demand!$C$7*75*'Bill of materials'!F20+Demand!$C$8*75*'Bill of materials'!G20+Demand!$C$9*75*'Bill of materials'!H20+Demand!$C$10*75*'Bill of materials'!I20)-(Inventory!L22*'Bill of materials'!D20)) ('Bill of materials'!E20) 'Bill of materials'!
=((Demand!$C$7*75*'Bill of materials'!F21+Demand!$C$8*75*'Bill of materials'!G21+Demand!$C$9*75*'Bill of materials'!H21+Demand!$C$10*75*'Bill of materials'!I21)-(Inventory!L23*'Bill of materials'!D21)) ('Bill of materials'!E21) 'Bill of materials'!
=((Demand!$C$7*75*'Bill of materials'!F22+Demand!$C$8*75*'Bill of materials'!G22+Demand!$C$9*75*'Bill of materials'!H22+Demand!$C$10*75*'Bill of materials'!I22)-(Inventory!L24*'Bill of materials'!D22)) ('Bill of materials'!E22) 'Bill of materials'!
=((Demand!$C$7*75*'Bill of materials'!F23+Demand!$C$8*75*'Bill of materials'!G23+Demand!$C$9*75*'Bill of materials'!H23+Demand!$C$10*75*'Bill of materials'!I23)-(Inventory!L25*'Bill of materials'!D23)) ('Bill of materials'!E23) 'Bill of materials'!
=((Demand!$C$7*75*'Bill of materials'!F24+Demand!$C$8*75*'Bill of materials'!G24+Demand!$C$9*75*'Bill of materials'!H24+Demand!$C$10*75*'Bill of materials'!I24)-(Inventory!L26*'Bill of materials'!D24)) ('Bill of materials'!E24) 'Bill of materials'!

Appendix C: Dataset of time studies

	Station 1:			Station 2:			Station 3:	
	Number of products packed:	Time elapsed: (s)		Number of products packed	Time elapsed: (s)		Number of products packed:	Time elapsed: (s)
1	5	8.22	1	2	3.62	1	2	4.01
2	5	8.69	2	2	2.28	2	2	2.28
3	5	7.37	3	2	2.84	3	2	3.54
4	5	9.16	4	2	2.43	4	2	2.47
5	5	11.78	5	2	2.78	5	2	1.81
6	5	6.22	6	2	2.44	6	2	2.35
7	5	9.67	7	2	3.07	7	2	2.73
8	5	9.18	8	2	2.19	8	2	2.66
9	5	7.75	9	2	5.22	9	2	2.21
10	5	6.69	10	2	3.69	10	2	1.66
11	5	10.35	11	2	3.68	11	2	2.41
12	5	4.50	12	2	3.07	12	2	3.84
13	5	5.27	13	2	3.00	13	2	2.31
14	5	7.05	14	2	3.00	14	2	1.69
15	5	4.28	15	2	2.72	15	2	3.71
16	5	5.54	16	2	4.53	16	2	2.47
17	5	9.75	17	2	5.19	17	2	2.22
18	5	6.40	18	2	3.35	18	2	1.44
19	5	5.31	19	2	2.41	19	2	2.57
20	5	8.41	20	2	5.06	20	2	4.17
21	5	8.00	21	2	2.94	21	2	3.13
22	5	13.00	22	2	3.65	22	2	2.71
23	5	9.44	23	2	2.31	23	2	1.78
24	5	7.75	24	2	2.40	24	2	3.13
25	5	10.09	25	2	3.87	25	2	1.47
26	5	8.13	26	2	2.85	26	2	2.00
27	5	7.25	27	2	2.85	27	2	2.41
28	5	6.66	28	2	2.00	28	2	1.59
29	5	6.25	29	2	4.78	29	2	2.25
30	5	9.00	30	2	6.59	30	2	1.56
31	5	9.40	31	2	1.84	31	2	2.00
32	5	6.60	32	2	2.07	32	2	3.16
33	5	7.53	33	2	3.04	33	2	2.12
34	5	8.75	34	2	3.19	34	2	2.18
35	5	7.25	35	2	3.19	35	2	2.38
36	5	8.19	36	2	2.09	36	2	1.16
37	5	8.68	37	2	3.63	37	2	2.00
38	5	9.56	38	2	3.72	38	2	1.91
39	5	7.65	39	2	2.19	39	2	1.96
40	5	9.98	40	2	2.71	40	2	2.16
41	5	5.59	41	2	1.91	41	2	1.12
42	5	5.40	42	2	2.66	42	2	1.72
43	5	5.12	43	2	3.69	43	2	2.63
44	5	3.59	44	2	2.72	44	2	2.91
45	5	6.03	45	2	2.16	45	2	2.57
46	5	8.85	46	2	2.43	46	2	2.28
47	5	7.25	47	2	2.75	47	2	2.16
48	5	11.63	48	2	1.84	48	2	1.56
49	5	11.34	49	2	2.25	49	2	2.06
50	5	9.45	50	2	3.03	50	2	1.15
	Mean =	**7.90**		**Mean =**	**3.08**		**Mean =**	**2.32**
	Standard deviation =	**2.05**		**Standard deviation =**	**1.00**		**Standard deviation =**	**0.71**

	Station 4:			Station 5:			Station 6:	
	Number of products packed:	Time elapsed: (s)		Hampers packed:	Time elapsed: (s)		Hampers packed:	Time elapsed: (s)
1	2	3.06	1	1	4.64	1	3	9.37
2	2	3.47	2	1	3.12	2	3	8.37
3	2	3.16	3	1	6.29	3	3	4.25
4	2	2.25	4	1	7.00	4	3	6.87
5	2	3.15	5	1	8.70	5	3	13.02
6	2	1.87	6	1	5.55	6	3	11.46
7	2	2.16	7	1	5.94	7	3	6.18
8	2	2.69	8	1	4.92	8	3	9.75
9	2	2.94	9	1	9.22	9	3	11.07
10	2	2.25	10	1	7.50	10	3	11.41
11	2	2.43	11	1	6.10	11	3	9.75
12	2	2.59	12	1	6.94	12	3	10.96
13	2	3.03	13	1	7.25	13	3	2.69
14	2	4.04	14	1	6.32	14	3	8.91
15	2	2.44	15	1	5.28	15	3	13.82
16	2	3.63	16	1	7.53	16	3	10.90
17	2	2.63	17	1	7.91	17	3	6.85
18	2	2.21	18	1	7.75	18	3	9.91
19	2	2.19	19	1	7.90	19	3	9.30
20	2	2.41	20	1	6.72	20	3	11.69
21	2	2.38	21	1	5.75	21	3	8.34
22	2	4.25	22	1	7.69	22	3	8.22
23	2	7.66	23	1	6.47	23	3	9.06
24	2	3.84	24	1	7.43	24	3	7.81
25	2	3.47	25	1	8.06	25	3	10.85
26	2	3.03	26	1	6.44	26	3	8.94
27	2	3.10	27	1	5.72	27	3	7.28
28	2	2.54	28	1	7.16	28	3	10.38
29	2	2.03	29	1	5.65	29	3	6.90
30	2	2.18	30	1	8.68	30	3	10.88
31	2	3.44	31	1	6.34	31	3	8.32
32	2	3.69	32	1	10.19	32	3	11.58
33	2	2.03	33	1	5.22	33	3	8.09
34	2	2.78	34	1	7.88	34	3	9.82
35	2	2.91	35	1	5.38	35	3	8.53
36	2	2.80	36	1	8.63	36	3	9.12
37	2	2.30	37	1	6.47	37	3	8.68
38	2	3.25	38	1	5.53	38	3	10.81
39	2	3.65	39	1	4.35	39	3	10.35
40	2	2.19	40	1	9.90	40	3	8.47
41	2	3.09	41	1	9.61	41	3	11.41
42	2	1.97	42	1	5.94	42	3	7.88
43	2	2.78	43	1	7.13	43	3	6.54
44	2	1.98	44	1	8.09	44	3	7.41
45	2	2.77	45	1	8.25	45	3	8.41
46	2	2.37	46	1	10.56	46	3	6.41
47	2	2.16	47	1	8.34	47	3	8.68
48	2	3.72	48	1	6.53	48	3	6.34
49	2	2.44	49	1	6.55	49	3	8.78
50	2	3.66	50	1	5.47	50	3	7.87
	Mean =	**2.90**		**Mean =**	**6.96**		**Mean =**	**8.97**
	Standard deviation =	**0.92**		**Standard deviation =**	**1.56**		**Standard deviation =**	**2.10**