



Layout Optimisation for the Automation of an Abattoir Packaging Department

BPJ 420

Final Year Project Report

30 September 2015

Martin Coetzer

Student Number: 10695304

Contact Details:

☎ Phone: 071 605 1494

✉ E-mail: martin.indeng@gmail.com

Executive Summary

Kroon's Gourmet Chickens is a chicken farm that rears its own chickens and processes these chickens so as to be sold to the public and major corporations. At the abattoir of the company, there is a continuous need to increase the throughput of the system as the demand for products is ever increasing and unsatisfied. The packaging department of the abattoir was identified by management as the bottleneck of the system, yielding the lowest throughput of all the departments within the company.

A thorough literature study is conducted in order to find, analyse and utilise various industrial engineering tools and techniques that analyses the current layout, aids in the process to identify weaknesses in the current layout, provides tools to generate, plan and optimise alternative layouts, to evaluate these layouts technically and economically, and to choose the layout that optimally satisfies the problem definition of the project. The problem definition is to increase the throughput of the packaging department of the abattoir of Kroon's Gourmet Chickens.

The Systematic Layout Planning methodology is the foundation according to which the project is conducted. The current layout of the abattoir and the packaging department is analysed using flow charts and relationship diagrams. The seven wastes are identified and analysed, with the adherence to the lean thinking methodology discussed. The economic aspects of the current layout that will influence the evaluation of alternative layouts are identified and discussed. Finally, the material handling techniques and the space requirements of the layout is analysed.

Two general approaches to the improvement of any production line's throughput are made. The approaches being automation and improved material flow routes within the department. For the automation alternative, plans are drawn up to implement two conveyors in the packaging department with aligning workstations to speed up the product flow of the department and to minimise the inter-departmental material flow. The improved material flow routes layout is designed with the intent to minimise the number of cross flow routes' intersection points of different materials within the department, and to decrease the amount of object and material sets travelling within the department. Flow process charts are drawn up for the two layouts and the products it delivers, being whole and portioned chickens, with the decrease in travelling and processing times calculated. These times are used as the basis for the economic analysis and the throughput evaluation between the layouts and the current layout in the evaluation of alternatives. The layouts' improvements on the seven wastes are discussed along with changes in any material handling techniques.

After the layouts were analysed by the Analytic Hierarchy Process model, according to criteria that best distinguishes the advantages of the layouts, being potential delays, ease of maintenance, throughput and annual operating cost, the best layout was determined as the layout design based on the conveyors in the department. This layout's score of the Analytic Hierarchy Process was 58.03%, with a throughput increase in the packaging department of 47.54%.

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Chapter 1

Introduction, Background and Need Requirements

Kroon's Gourmet Chickens' managing directors observed that there is a continuous need to increase the throughput of the company's abattoir, as the demand for products continues to increase and is unfulfilled. The packaging department was identified as the bottleneck-department of the abattoir, as this department has the lowest throughput. It was decided by management that an external analyst should investigate the current systems of the packaging department.

The project focusses on increasing the throughput of the packaging department of the abattoir by analysing the department layout, work flow and the type of equipment that is used and making recommendations as to how it can be improved.

1.1. Establishment of Kroon's Gourmet Chickens

Kroon's Gourmet Chickens is a family business that started in 1976 when Pauline Kroon, the mother of the family, began providing fresh chickens to the public in an effort to earn an additional small income.

The business boomed and in 1986 the location of operations moved from their home to a much larger area in Wildebeesthoek in the De Wildt area on the way to Brits from Pretoria. Robert Kroon, the father of the family, joined the business full-time in 1986. By 2001, all three Kroon children have joined the family business as full-time employees, working together to expand the company and perfecting process techniques. As of today, Kroon's Gourmet Chickens operates as a medium to large chicken farm and supplies fresh produce nation-wide.

1.2. Background on the Workings of Kroon's Gourmet Chickens

To understand why the abattoir's throughput is increasing, and needs to continue increasing without disrupting the supply chain, one first needs to understand how the company works.

Kroon's Gourmet Chickens sells only fresh chickens, chickens slaughtered today must be sold today. The company buys two to three day old chicks in bulk and rears them in chicken houses on site. Kroon's Gourmet Chickens buys chicks and food for the rearing of all chickens. The company also outsource the rearing of chickens, providing the chicks and food to external contractors and collecting the chickens when they reach the desired weight for further and immediate processing in the abattoir.

For argument's sake, and to keep the information of Kroon's Gourmet Chickens' operations confidential, let the company have three on-site rearing houses and three houses which are owned and managed by a third off-site contracting company. These six houses should be supplied with chicks; the chicks should be vaccinated, fed and their weight and health should be monitored. Chicks take four to six weeks to reach the desired weight to be sent to the abattoir, but all six houses' chickens can't be sent to the abattoir at the same time. Each house contains at least 15000 chickens which are all delivered to the abattoir at the same time.

Management has implemented a cycle process wherein the houses' chickens' levels of maturity at the different houses must be created and maintained, to ensure that the houses are ready for slaughter when needed. Not all houses must be ready at the same time.

The houses' levels of maturity of the chickens must have a cycle from which the houses are ready at different times, and that there is always a house ready when needed. The time that a rearing house must be ready is determined by demand forecasted for fresh chickens on a given day. The total demand for the day's chickens must be collected and processed in the abattoir. The company does not maintain mixed-age rearing houses, so an entire rearing house is emptied and processed in the abattoir. An emptied rearing house should then be cleaned, balanced with the acceptable temperature and humidity, disinfected and stocked with food and water for the arrival of one to three day old chicks.

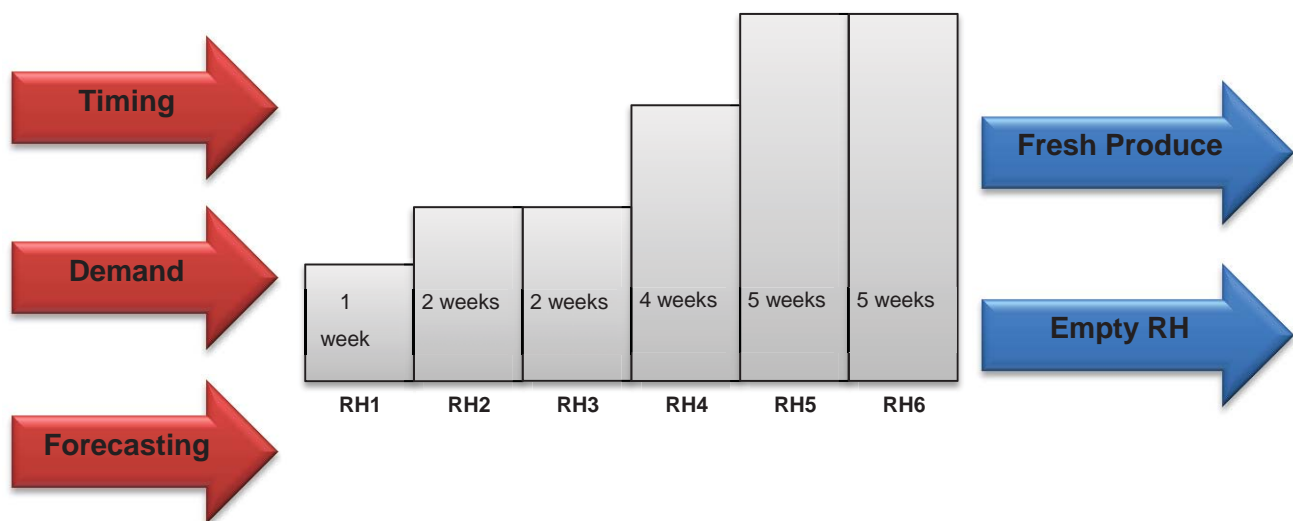


Figure 1: Rearing Houses' Cycles

This cycle is quite dynamic, and requires intense and accurate planning for if one element of this operation is delayed, an entire supply network can crash due to a multitude of factors, including but not limited to:

- ❖ New chicks cannot be housed,
- ❖ Customers are lost permanently due to demand not met,
- ❖ Fresh produce is lost as no freezing facilities are available,
- ❖ Income lost due to lowered prices or lost produce,
- ❖ Chickens in rearing houses that exceeds the intended days of rearing grows too big for optimum slaughtering size, and
- ❖ Entire demand and supply forecasting plan must be drawn up from the start.

1.3. Background on the Abattoir's Processes

The abattoir's operations cannot, even for half a day, come to a stand-still, for reasons made clear in section 1.2. Rearing of chickens can be outsourced, but the abattoir processes cannot be outsourced. This means that the abattoir is the lead factor in determining the company's throughput. The faster the abattoir can process produce, the more customers can be supplied.

The abattoir's processing of chickens from livestock to cool and packaged produce consists of four main processing cycles. The first cycle, as seen in Figure 2 **Error! Reference source not found.** is the off-loading and preparation. The abattoir has a deck onto which the delivery trucks load the crates of chickens where staff inserts the chickens manually from the crates onto the abattoir feeding line. The chickens are stunned at a high voltage before they are drained of their blood via a manual cut to the main neck arteries. Still in the first cycle, the chickens are rapidly boiled in order to open the pores to ease the feather removal process prior to being beheaded.

The second cycle is the de-feathering cycle. On the same processing line from the first cycle, the chickens are run through an automated de-feathering machine which completely removes the chickens' feathers. The chickens' feet are then manually cut off, while the chickens are transferred via a chute to the third cycle.

In the third cycle, the chickens' gizzards are removed by machines and the chickens and gizzards are manually inspected to ensure that each chicken is completely healthy. After the removal of the gizzards, the chickens are rapidly cooled to a low temperature before being processed for packaging.

In the fourth, and final, cycle, the produce is manually weighed on scales, packed in different weight-groups, some being portioned, and finally packed and transported to the coolers to await pick-up by the customer.

As the company wishes its figures to stay confidential, a converting factor will be used in the subsequent reports to use the throughput of the abattoir and of each cycle in calculations, and in the final proof of an increase in the throughput.

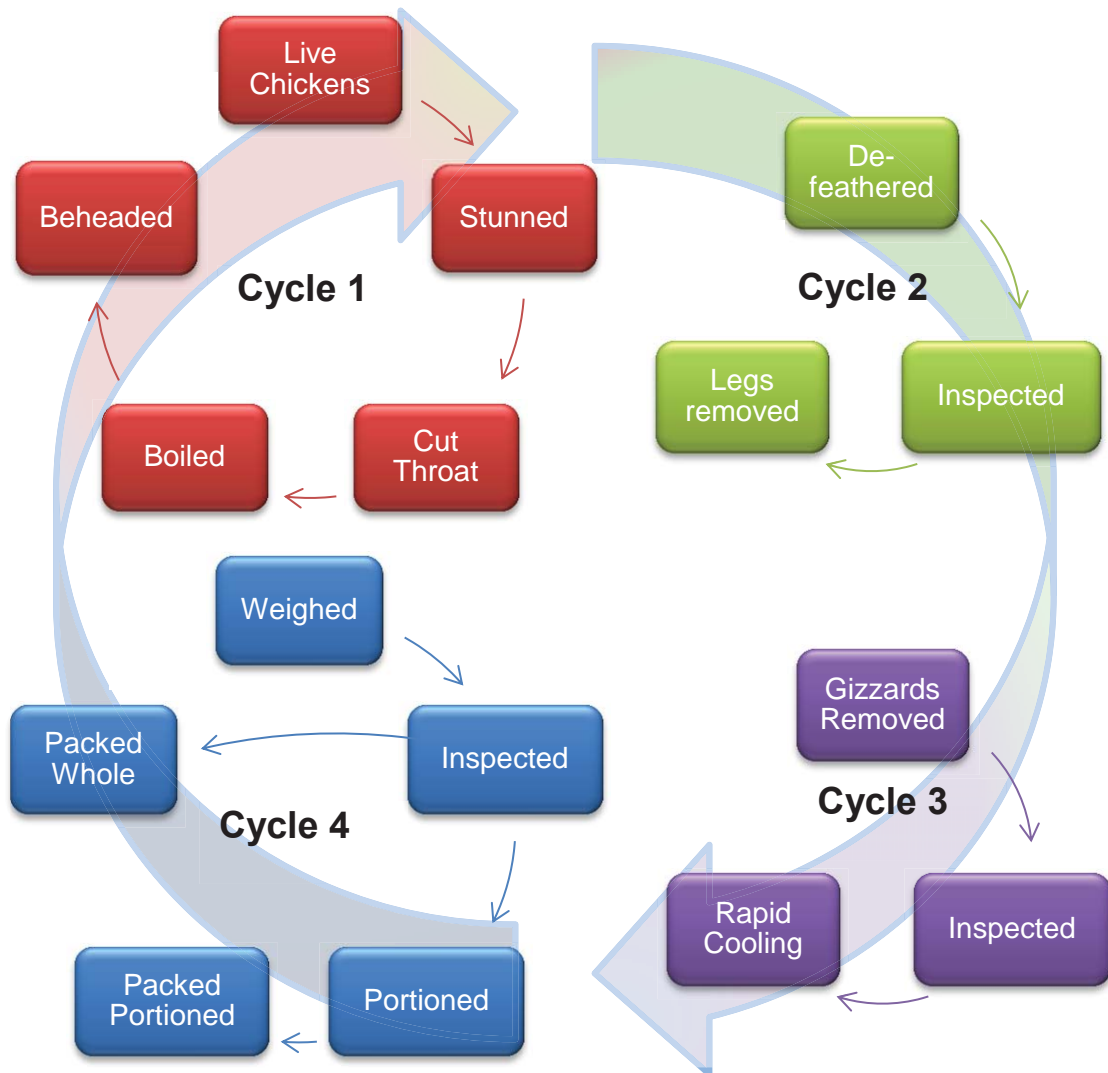


Figure 2: Abattoir Cycles

1.4. Need Requirement Analysis

A proper investigation and analysis for any need or requirement and its causes must be conducted to determine whether there is a need for a solution to this requirement. There are different investigation and analysis techniques that can be applied to various types of problems and requirements.

The need in this project is to determine whether it is possible to increase the throughput of a production system, in this case, an abattoir. From another perspective, whether it is possible to improve the productivity of the supply chain by thoroughly analysing and improving the productivity of the supply cycle. Productivity in its essence according to Smith, (Smith, 2004) is an expression of the quantity of goods produced in comparison to the quantity of resources utilised to produce it. These resources used include capital, labour, energy and any other resource used in the process to produce the manufactured or processed products. Before any analysis can be done on the scope and the importance or relevance of the need, a clear understanding on the background and the environment of the project must be gained.

1.5. Project Aim

The aim of this project is to determine whether it is possible to increase the throughput of the abattoir packaging department without expanding the facility by means of construction or relocating the entire facility. There is a need to increase the throughput of the abattoir and the farm's supply cycle as a whole, due to the continuous increase in demand for the products of Kroon's Gourmet Chickens. When using an example value of R5 that can be made on profits per chicken sold by the company, a small increase in the throughput of 50 chickens per hour can cause a potential increase of R44 000 per month, given that the abattoir runs for 8 hours per day in a 22 day month. This proves that any increase in the throughput of the abattoir will be a financial gain for the company.

1.6. Project Scope

This project entails the optimisation of the throughput of Kroon's Gourmet Chicken's abattoir. An in depth analysis of the abattoir packaging department's as-is systems and processes will be done. Alternative layouts and processes of the abattoir packaging department will be generated and evaluated. Industrial engineering tools and techniques from different fields will be used to analyse the as-is state of the facility, to design alternatives for an improved packaging department and to evaluate the alternatives designed.

Chapter 2

Literature Review

2.1. Goals of Facilities Planning

The facilities we plan today must help an organisation achieve supply chain excellence.

Tompkins et al. (2010)

2.1.1. What is Facilities Planning?

In order to stay ahead of competitors in the market, a continuous advancement in technology used, management techniques and resource utilisation techniques must be made. Facilities planning is one very important tool that must be continuously maintained, researched and advanced upon in any company's environment. In short, facilities planning is a strategy, a strategy to achieve supply chain excellence (Tompkins et al, 2010). Supply chain excellence cannot be achieved if a facility has a poor layout which has obstructions and delays all the time.

Supply chain excellence is a process with the following steps (Tompkins et al, 2010):

- ❖ *Business as usual*: Each element and department within the organisation works hard to function well within its individual element.
- ❖ *Link excellence*: The various elements and departments within an organisation must continuously strive towards excellence in inter-departmental workings in order to function as one thriving supply chain.
- ❖ *Visibility*: Every element in the supply chain must be able to see or visualise the supply chain as a whole with all its interactive elements and its respective progress states.
- ❖ *Collaboration*: The supply chain, all the elements in the organisation, works together to maximise customer satisfaction while keeping inventories to a minimum.
- ❖ *Synthesis*: The boundaries between the links in a supply chain must be removed in order to unify all the links and to form one chain as a whole.
- ❖ *Velocity*: Speed is a necessity in any thriving, growing organisation, to get as much produce as possible to as many customers in the shortest amount of time.

Tompkins (Tompkins et al, 2010) states that facilities are important components of any supply chain in order to achieve supply chain excellence. Each element's facility in a supply chain must therefore be designed while bearing all other interacting elements in mind. To achieve this method of design, all facilities must strive towards the following characteristics:

- ❖ *Flexibility*: This characteristic enables a facility to handle and process a variety of procedures and requirements without being physically altered.
- ❖ *Modularity*: Modular facilities are facilities which can efficiently operate on its own without any major influences from other facilities.
- ❖ *Upgradability*: This design incorporates the advances in technology and equipment systems.
- ❖ *Adaptability*: The implications of cycles and seasonal trends are taken into consideration.
- ❖ *Selective operability*: A complete understanding of how each element in the facility operates with the support of contingency plans in place.
- ❖ *Environmental and energy friendliness*: A building method to sustainability in site expansion, water savings, energy effectiveness, resources selection and indoor environmental value

2.2. Importance of Facilities Planning

Facilities planning has proven in numerous situations to play a vital role in the success of any organisation's functions and processes. According to Tompkins (Tompkins et al, 2010), facilities planning represents one of the areas with the most potential for increasing the rate of productivity advancement. It has been statistically proven that between 20-50% of operating expenses in manufacturing is attributed to material handling. With the right facilities planning techniques applied, a savings in these costs of at least 10-30% can be achieved. If proper order picking systems and relevant equipment according to facilities planning guidelines are used, distribution centres' total cost of operations have been known to reduce by 30%. If any organisation continually updates the systems, processes and machinery to stay ahead of competitors in the industry and to be as efficient in production as possible, then there must be a continuous rearrangement and re-layout of the facility and its process flows.

2.2.1. Objectives of Facilities Planning

Customer satisfaction should be the main objective of facilities planning, just as supply chain synthesis is driven by customer satisfaction. This will ensure that the goal of facilities planning is in line with the organisation and supply chain goals (Tompkins et al, 2010).

Some facilities planning objectives according to Tompkins (Tompkins et al, 2010) are to:

- ❖ Increase overall customer satisfaction by responding to needs
- ❖ Increase return on assets (ROA)
- ❖ Maximise velocity regarding customer response
- ❖ Reduce costs and develop supply chain profitability
- ❖ Integrate the supply chain by means of communication
- ❖ Effectively utilise equipment, people, space and energy
- ❖ Provide for employee safety, job satisfaction, energy efficiency, and environmental responsibility
- ❖ Provide sustainability assurance

It is important to analyse and evaluate the performance of each alternative using the appropriate criteria most applicable to the nature of the organisation's operations.

2.3. Facilities Planning Approaches

There are various approaches based on facilities planning that can be used to analyse a project. The methodology and content of the various approaches will be discussed regarding the limitations and advantages of each, based on the nature of this project and the project environment.

2.3.1. Systematic Layout Planning

A combination of the Systematic Layout Planning (SLP) methodology, as discussed by Tompkins (Tompkins et al, 2010), and the traditional engineering design process will be used to analyse the current layout of the facility and to implement any modifications that will be made to the current layout with its processes. The SLP must be used in this manner in addition to staying focused on the problem at hand and the main objectives of the project.

The SLP methodology that will be used to analyse and successfully complete this project will be (Tompkins et al, 2010):

1. Define the objective of the facility: Discuss the objective of the facility and the deliverable as required by the organisation.
2. Analyse the problem: Determine the interrelationship between the elements contributing to the final outcome of the analysed department.
 - ❖ Document current activities using existing data and facility plans
 - ❖ Define all activities and elements in the department
 - ❖ Illustrate the flow of materials in the department
 - ❖ Design a relationship diagram between existing activities
3. Determine space available and identify space requirements for all activities and equipment.
4. Illustrate the space requirements via space relationship diagrams and block layout diagrams.
5. Identify constraints and practical limitations that the project environment may have on the successful completion of the project.
6. Generate alternative facility plans by identifying aspects and flow paths that are unnecessary or time inconsiderate.
7. Evaluate layouts by means of practicality and space constraints. Provide evidence on the best layout's potential performance in comparison to the unsuited layouts.
8. Select the preferred design and provide an overview of the workings of this layout.

As the methodology that will be used is discussed above, the elements that will be included in the scope of the project in order to ensure successful completion shall not be limited by the elements described above. Modifications to the methodology may be made, but the steps described will serve as a guide to ensure all aspects of a thorough analysis are covered.

2.4. Tools and Techniques for Facilities Planning

A facilities planning approach to any problem provides various tools and techniques that can be applied to the analysis of the abattoir to yield a more qualitative understanding of the workings of the abattoir.






2.4.1. Flow Process Chart

The flow process chart gives a highly detailed description of the process that is currently implemented in the system section being analysed (Freivalds, 2009). However, it does not provide a pictorial plan of the flow of materials and work within the system. Thus, it is vital that the flow process chart be used in combination with an aerial view of the process flow, called a flow diagram, in order to get a clearer understanding of the flow of work.

A template that will be used for the flow process chart, was obtained from Freivalds (2009: 36). The symbols used to illustrate the steps in the process depicted in

Table 1.

Table 1: Process Flow Chart Symbols

Symbol	Description
	Process
	Process / material flow or movement
	Delay in the process
	Decision regarding the product
	Inventory/ Buffer/ Warehouse

The flow process chart will be used to analyse the current and proposed layouts of the packaging department. The savings in time can be calculated on the new layout's flow process chart. This chart is a very good tool to aid in the process of identifying unnecessary steps or delays in the system.

2.4.2. Activity Relationship Diagram

An activity relationship diagram is a diagram which depicts the importance of the proximity between elements and activity stations in a department or process. It is a tool that helps identify any current layout proximity areas of improvement. An activity relationship diagram is done for the areas interacting within the packaging department in section 4.3.2. However, a different format may be used in this report in order to simplify the use of the diagram. The symbols that will be used in the top half of the proximity rating allocation space in the diagram are:

Table 2: Activity Relationship Diagram Ratings

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

The symbols that will be used in the bottom half of the proximity rating allocation space in the diagram are:

Table 3: Reasons for proximity value




Code	Reason
1	Flow of Material
2	Convenience
3	Same personnel
4	Cleanliness

More reasons may be added during the completion of the project in order to better motivate the reasons for the proximity rating allocated.

2.4.3. Relationship Diagram

A relationship diagram positions the volume of activities and their flow according to the space available in the working environment (Tomkins et al, 2010). The activities are positioned on an aerial sketch of the facility according to their actual location and rough proximity towards the other activities. The activities are then linked by lines which indicated the different flow volumes of material between stations in the facility being analysed. The lines' representation legend is as follows:

Table 4: Flow Rate Legend, Relationship Diagram

Line	Flow
	Low rate (Less than 20% of flows)
	Medium rate (20-50% of flows)
	High rate (more than 50% of flows)

2.4.4. Space Relationship Diagram

The space relationship diagram is identical to the relationship diagram, except that the space relationship diagram illustrates the amount of space each activity occupies by a square relative to the size of the other activities' special squares. If there is enough space to clearly illustrate the volume of the products' flow in the space relationship diagram, the space relationship diagram and the relationship diagram will be combined in one diagram. These

two diagrams are important in identifying activity stations that have a high flow rate of products but are located far from each other relative to the other stations.

2.4.5. Block Layouts

The Systematic Layout Procedure gradually works towards block layout alternatives, then to be illustrated into detailed layout plans for the department (Tompkins et al, 2010). Block layouts illustrate the areas in a department with the same function with a block on an aerial sketch of the department's perimeters.

2.4.6. Detailed Facility Layout Plan

A detailed facility layout plan is a highly detailed illustration of the facility, using the relationships between the machines, workstations, storage locations, and entrances and exits to determine the relative location in each block of the block layout.

The detailed facility plan is the final analytical tool that is used to depict and illustrate the workings of the abattoir. From this plan the main elements of the alternative layouts for the abattoir shall be determined.

2.5. Optimising Production

During the completion of this project focus must be kept on eliminating any unnecessary processes and all forms of 'waste'. The Lean Thinking approach and eliminating the Seven Wastes will be discussed in order to gain insight into the roots and causes of the wastes and to enable the organisation to better identify any process or activity that does not benefit the customer and the organisation.

2.5.1. Seven Wastes

The team that designed the Toyota Production System identified three types of 'waste' or activities that do not increase the performance of the organisation or that does not add value to the final product to be delivered to the customer, and named these three activities muda, mura and muri (Eaton, 2013).

- ❖ *Muda* is an activity that does not add value to the customer's product. Muda is also called 'waste'.
- ❖ *Mura* is a variation in a process due to some irregularity or imbalance in the system, also called 'unevenness'.
- ❖ *Muri* is putting unnecessary or unreasonable stress on employees, materials or equipment, also called 'overburden'.

Taiichi Ohno of Toyota categorised seven types of non-value-adding activities. More and more organisations add an eighth waste, namely 'talent' (Eaton, 2013). According to Eaton, the seven, and eighth, wastes are:

1. *Waiting*: Waiting for parts or elements to arrive at a process.
2. *Overproduction*: Producing more products that are required by the customer/s.
3. *Rework*: Undertaking a task more than once due to incorrect processing the first time.
4. *Motion*: Movement of human beings, whether contributing or not contributing to the completion of the process.
5. *Transport*: Movement of equipment, information and/or materials.
6. *Processing*: Undertaking any activity that is explicitly not required by the customer or regulations.
7. *Inventory*: Costs of holding, managing, storing and disposing of products.
8. *Talent*: This is a waste of expertise by human beings by expecting them to complete tasks that would be better undertaken by another person or not done at all.

Now that wastes are identified, the Lean Thinking approach and its importance regarding application in any modern organisation can be discussed.

2.5.2. Lean Thinking

To apply the Lean Thinking approach to any organisation, it must first be perfectly understood what is meant by 'lean'. The definition of 'Lean' revolves around three key aspects (Eaton, 2013), namely:

1. The focus must be to deliver higher valued products and services to the customer.
2. To deliver more with less resources.
3. To not put quality, safety or long-term organisational stability at risk when 'delivering more with less'.

Lean's main focus is to direct the goal of processes to the customers' needs by considering and eliminating everything that is classified as waste to the production system.

In the book “*Lean Thinking: Banish waste and create wealth in your corporation (1996)*”, written by James Womack and Daniel Jones, they developed a five-step thought process, 5 Lean Principles, based on the origin of the thought process that led to improved performance at Toyota (Eaton, 2013). The 5 Lean Principles are (Eaton, 2013):

1. Define ‘value’ from the customer’s perspective.
2. Understand the value stream used to deliver value currently.
3. Create processes that flow.
4. Trigger activity when the customer ‘pulls’.
5. Aim for perfection.

When keeping in mind that value must be added, the customer’s needs must be fulfilled and that wastes must be eliminated in every element of the system, not only the throughput of the abattoir will be increased, but the customers will also be more satisfied with the value of the products provided. Capital will be saved at unexpected, previously unidentified aspects of the system.

2.6. Economic Analysis

Engineering economy relates to the formulation, estimation and evaluation of the economic outcomes of available alternatives when a defined objective must be achieved (Park, 2013). In this project, the economic factors of the alternatives will be compared to the as-is functions and layout of the facility in order to determine which alternative layout will benefit the organisation best in the future.

2.6.1. Costs to Consider

In an economic analysis, costs of various elements of each alternative must be analysed. It is important that all the costs included in the analysis of the alternatives are the same for each alternative, if the alternative has such a cost present. Present costs that are the same in each alternative may be neglected from the study, such as the rent of the warehouse or management employees (Seal et al, 2012). The following costs will be included in the economic analysis of each alternative:

1. Labour cost: The cost of the wages and/or salaries of the employees working in the packaging department.
2. Acquisition cost: The cost to acquire, if any, new equipment or assets.
3. Maintenance cost: The cost to maintain assets.
4. Sales: The average price paid by a customer when one (1) chicken is bought.

The costs calculated will be illustrated in a break-even analysis where a more clear comparison between the alternatives’ economic influences can be made.

2.6.2. Net Present Value

The net present value (NPV) is calculated in order to determine whether an economic investment is worth undertaking, or not. A project will be worth the investment if the (NPV) is more than 0. The alternative with the highest NPV will be the most feasible one (Cholet, 2009). This method applies a fundamental economic analysis concept known as Time Value of Money. In essence, the application of the concept converts any future expenditures or profits made to a single NPV. The alternatives evaluated by this method must all have the same time period under which they are evaluated. Any expenditure will add to a negative NPV, and any income obtained will add to a positive NPV (Park, 2013).

2.6.3. Break-even Analysis

A break-even analysis determines the point in time, if any, when a proposed solution becomes profitable, after x-amount of sales. The amount of sales needed for the system to be profitable can be converted, using the throughput of the system, to the amount of time it will take for the system to become profitable.

The formula to determine this break-even point, according to Seal (Seal et al, 2012) is:

$$\text{Sales} = \text{Variable expenses} + \text{Fixed Expenses} + \text{Profits}$$

With a profit of zero (0), and the sales being:

$$\text{Sales} = \text{Sales price} * \text{Amount of products sold}$$

The amount of products sold as an unknown, 'x', it can be determined how many products must be sold for the system to reach a zero (0) profit. The amount of products is then divided by the throughput to yield the total amount of hours needed to reach the break-even point, which can be converted to any convenient time unit.

However, as the abattoir is only one department of the entire organisation, the amount of products sold and the sales made thereof, can not be regarded as profit for the abattoir only. The overhead and expenses of the entire organisation must be subtracted from the sales made as products of the abattoir. A monetary value of R1 will be used to represent the net profits per chicken processed and sold by the abattoir when evaluating the alternatives. This value is only a representation of the profits made by one chicken sold, so as to keep financial data of Kroon's Gourmet Chickens confidential.

2.7. Material Handling

The methods and equipment used to transport and move the produce only in the packaging department of the abattoir will be analysed, assessed and, if necessary, have alternative methods and equipment analysed in order to improve the system performance. This is an important analysis due to the fundamental role of material handling in the throughput of the department.

2.7.1. Containers

Containers are frequently used to enable the movement and storage of loose products (Tompkins et al, 2010). As the products in the packaging department are rather small, it would be easier and more efficient if the products are moved in a tote pan. Tote pans are used to unitise loose items (Tompkins et al, 2010). Empty tote pans can be stacked to ensure high space utilisation. Skid boxes are impractical and too heavy for application purposes in the packaging department. Pallets will not be necessary as the tote pans can individually be moved by hand and the products will not be transported safely on pallets.

Tote pans can either be moved by forklifts on pallets or hand trucks or hand carts. Hand trucks and carts are of the simplest and economic kinds of material management equipment used for not so heavy loads and short distances (Tompkins et al, 2010).

2.7.2. Conveyors

Conveyors are used when products are to be moved between set, specific points over a fixed path in frequent intervals (Tompkins et al, 2010). There must be a sufficient volume of movement of materials or products to justify the use of a conveyor. There exist a wide range of conveyors that can be used in the packaging department. In order to determine which type of conveyor may best suit the requirements of the packaging department, the type and size of materials must first be identified, whether bulk or units. In the packaging department, products to be transferred can be bulk, tote pans, or in units, pieces of fresh produce or packed and sealed produce.

Relevant conveyor types applicable to the materials to be handled in the packaging department are (Tompkins et al, 2010):

- ❖ *Flat Belt Conveyor*: These conveyors are usually implemented when light- and medium-weight load materials are to be transported between operations, departments or levels, and even buildings. The belt is usually either roller or slider bed supported.
- ❖ *Roller Conveyor*: A characteristic which makes the roller conveyor very popular is that it may be powered or non-powered. Non-powered rollers' loads can be manually moved by workers and may have a slight incline to improve movability by the aid of

gravity.

Powered roller conveyors have various methods to being powered. They are generally powered by belts or chains. Revolving drive shafts can also be used to power a roller, connected to the drive shaft by an elastomeric belt. Electric motors can also be housed inside rollers to power it. Because of the roller surface, the products being transported must have a firm riding surface.

- ❖ *Chain Conveyor*: This type of conveyor consists of one or more endless chains on which loads are carried directly. They are often used to transport tote boxes or pallets as only two or three chains are generally required to provide enough contact with the rigid support or container to enable movement.

2.7.3. Cranes

Hoists and cranes are used to move heavy loads of equipment or materials in the same general area. Hoists and cranes are too expensive for the practical applications necessary in the packaging department.

2.8. Space Requirements

“Work expands to fill time available and expenditures rise to meet income.”

Cyril Northcote Parkinson

Applying this statement of C.N Parkinson to the methods of facilities planning, it states that things will always expand to fill the available capacity sooner than planned (Tompkins et al, 2010). Space requirements are one of the most important factors to consider when designing or redesigning a workspace as it limits the number of optimal production solutions. In fast expanding companies the space requirements increases and the predetermined working space will eventually not be enough to perform the required activities.

The following factors, if applicable should be considered when determining the space requirements for a facility (Tompkins et al, 2010):

- ❖ Inventory levels
- ❖ Storage units
- ❖ Storage methods and strategies
- ❖ Equipment requirements
- ❖ Building constraints
- ❖ Personnel requirements

The planned for a facility is typically five to ten years (Tompkins et al, 2010). It is important that space requirements be planned from ‘the ground up’. Start by determining the space requirements for the individual workstations. Calculate the departmental requirements next

by “including” the space required by the workstations as well as the aisle spatial requirements. The facility will then require the space as required by all of the departments.

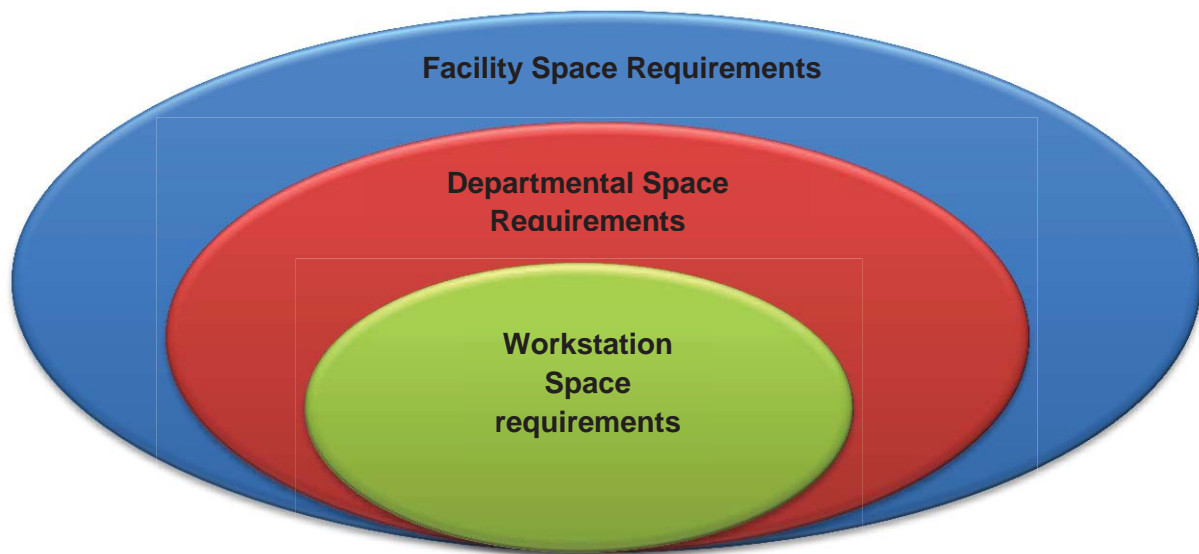


Figure 3: Space Requirements: From the Ground Up

2.8.1. Workstation Specifications

The productivity of a facility is related to the productivity of the facility’s individual workstations (Tompkins et al, 2010). A workstation includes space for machinery, materials that are used in the workstation and personnel present within the workstation. The equipment or machinery space for any workstation includes enough space for, (Tompkins et al, 2010),

1. Machinery,
2. Machine transport,
3. Machine upkeep, and
4. Plant services.

Equipment space requirements should be available from equipment data sheets. Adding the machinery areas together for all of the machines in a workstation provides the machinery space requirement for the workstation (Tompkins et al, 2010).

The materials areas of a workstation include space for, (Tompkins et al, 2010),

1. Receiving and storing inbound materials,
2. Holding in-process materials,
3. Storing outbound materials and shipping,
4. Storing and shipping waste and scrap, and,
5. Holding tools, fixtures, jigs, dies, and maintenance materials.

Unit loads to be handled and the flow rate of materials through the machine must be known so that area requirements for the handling or management of materials can be determined. Space for waste and scrap must be provided for within the workstation.

The personnel area in a workstation should include space for, (Tompkins et al, 2010)

1. The operator work area,
2. Material handling, and
3. Operator ingress and egress.

Operator ingress and egress space requirements are

- ❖ Traveling past stationary objects: 76cm
- ❖ Traveling between an operating machine and a stationary object: 92cm
- ❖ Traveling between two machines which are operating: 107cm

The following guidelines can be used when determining the material handling space requirements for personnel within a workstation (Tompkins et al, 2010):

1. Operators should be able to pick up and discharge materials without having to walk or make long reaches.
2. Operators should be utilised efficiently and effectively.
3. Manual material handling time should be minimised.
4. Operator safety, comfort and productivity should be maximised.
5. Hazards, fatigue and eye strain should be minimised.

All of the space requirements calculated are approximations. These approximations will be used to determine whether all of the equipment and personnel can fit into the constraints of the facility perimeters. The aim here is to calculate these requirements as accurate as possible so that none, or very few, modifications will be necessary at the implementation of the final layout alternative.

2.8.2. Department Specifications

Department space requirements are not calculated by simply adding the space required for all the workstations within the department. There may be equipment and personnel shared between workstations in order to save space and resources. Also, extra space is necessary in all departments for material handling.

Aisles should be designed with promoting effective flow as the main objective. Aisle widths should be designed by bearing in mind the amount of flow the aisle will have to carry. Recommended aisle widths for various types of flow are (Tompkins et al, 2010):

- ❖ Narrow aisle truck: 1.8m
- ❖ Manual platform truck: 1.5m
- ❖ Personnel: 0.9m
- ❖ Personnel with doors opening into aisle: 1.8m

If the expected flow in an aisle results in two-way flow occurring regularly, the aisle width should be equal to the sum of the aisle widths needed for the individual flow requirements in each direction (Tompkins et al, 2010).

The facility space requirements will be the space requirements of all the departments with the various aisles, roads and additional material handling equipment with functionality-rooms and storage units. The scope of this project does however, not include the space requirements of the entire facility. Only the space requirements of the packaging department will be determined.

2.9. Comparison between Alternatives

After alternatives are generated, the optimal layout must be chosen. There are a lot of techniques available to conduct multiple objective decisions. These decisions must be made by analysing and choosing between two or more alternative solutions by comparing and rating these alternatives to more than two factors. Without any mathematical or statistical aid, these decisions can become quite difficult to make without the right supporting evidence.

Two multiple objective decision making techniques will be discussed of which both can be applied to the project, the weighted factor comparison method and the Analytical Hierarchy Process.

2.9.1. Weighted Factor Comparison

The weighted factor comparison method is a very popular method in comparing and deciding between alternatives in any applicable field. Factors of importance relative to the main deliverable of the project are identified and numerical values, or weights, are assigned proportionally based on its degree of importance. Each alternative is then rated according to these factors of a numerical value of 1 to 10. The values of each alternative layout are then converted using the weights of the factors and are summed over all factors to obtain a total weighted score (Tompkins et al, 2010).

Care is required to avoid the halo effect when using this method. The halo effect is caused by a high ranking on one factor that influences the ranking on other factors. If one alternative clearly dominates all other alternatives on almost all factors, the chances are high that the halo effect is present (Tompkins et al, 2010).

Factors provided by Tompkins (2010: 758-759) applicable to the scope of this project includes, but are not limited to:

- ❖ Initial investment needed
- ❖ Annual operating costs
- ❖ Return on investment (ROI)
- ❖ Potential delays
- ❖ Software requirements
- ❖ Ease of maintenance
- ❖ Employee resistance to change
- ❖ Space utilisation
- ❖ Throughput improvement
- ❖ Ease of future expansion
- ❖ Safety and housekeeping
- ❖ Frequency and seriousness of potential breakdowns
- ❖ Effect on in-process time
- ❖ Supporting services required
- ❖ Degree of automation

A shortcoming of the weighted factor comparison method is that the results of the decision matrix, containing the alternatives versus the rating factors, may contain inconsistencies in the sense that the factors' values were determined qualitatively by some rule of thumb or human instincts where these influences may be biased or unreliable. If the results from a multiple objective criteria decision making process will be used as the basis of a very important or highly valued project, it is recommended to use the analytic hierarchy process as unbiasedness can be proven when determining the risks regarding the project's successful completion.

2.9.2. Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is a multiple criteria decision making process that is, according to Pillay and Wang (Pillay & Wang, 2003), "the most highly regarded and widely used decision-making theory". The AHP is so effective because it enables decision making to include both qualitative and quantitative aspects for consideration. It reduces complex decisions to a series of pairwise comparisons of the factors that will be the basis of the decision making process.

When deciding on a set of criteria that is to be included in the evaluation process, the main objectives are (Saaty, 1980):

1. To deliver judgement on the relative significance of these criteria.
2. To guarantee that the judgements are quantified to a degree that also permits a quantitative interpretation of the judgements among these criteria.

There are three steps to successfully execute the AHP are (Vasant et al, 2012):

Step 1: Construct the pairwise comparison matrix. Let $E_1, E_2 \dots E_n$ be a set of elements from which the alternatives will be evaluated upon. And let a_{ij} represent a quantified judgement on a pair of elements E_i and E_j . The relevant importance of two elements is rated according to Table 5:

Table 5: Importance Values of the AHP

Quantitative Value	Description
1	equally important
3	slightly more important
5	strongly more important
7	demonstrably more important
9	absolutely more important

This will produce the $n \times n$ square comparison matrix where

- $a_{ij} = 1$ for $i,j=1,2 \dots n$
- $a_{ji} = 1/a_{ij}$ for $i,j=1,2 \dots n$

$$- A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ 1/a_{12} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \dots & a_{nn} \end{bmatrix}$$

Step 2: Normalise the comparison matrix and obtain the weights.

$$\text{Let } A = \begin{bmatrix} 1 & a_{12}/t_2 & \dots & a_{1n}/t_n \\ a_{21}/t_1 & 1 & \dots & a_{2n}/t_n \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1}/t_1 & a_{n2}/t_2 & \dots & 1 \end{bmatrix}$$

$$\text{And } t_j = \sum_{i=1}^n a_{ij}$$

The weights are obtained by computing the average of each row, yielding $w_1, w_2 \dots w_n$. The weights are used at the finalisation of the AHP to calculate the sum of the totals of each alternative's ratings obtained in the criteria evaluation process.

Step 3: Calculate the Consistency Index (CI) as:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

' λ_{max} ' is the largest eigenvalue of the $n \times n$ reciprocal pairwise comparison matrix A and 'n' is the number of columns or rows in the square matrix.

The Consistency Ratio is given as:

$$CR = \frac{CI}{RI}$$

'RI' represents the average consistency index over numerous entities of the same order reciprocal matrices. The RI values for different order reciprocal matrices are (Peláez & Lamata, 2003):

Table 6: Random index values for different order matrices

N	1	2	3	4	5	6	7
RI	0	0	0.58	0.9	1.12	1.24	1.32

Saaty (Saaty, 1980) states that a CR value of less than or equal to 0.1 indicates that the decision maker is consistent in judgement.

Consistency ratios are also calculated and implemented in the judgment process of alternatives at the various criteria according to which the alternatives are being evaluated upon.

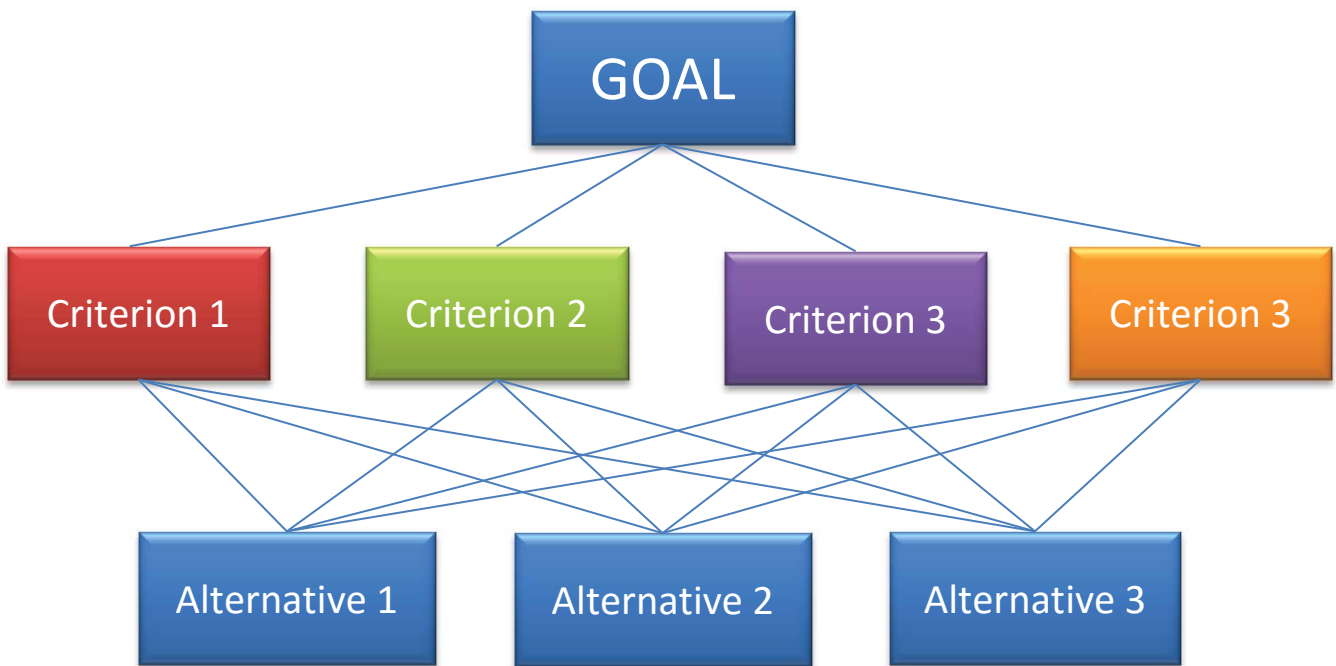


Figure 4: Multiple Objective Decision Making

As it is very important that the decision maker is consistent in judging criteria which will be the basis of accepting or rejecting alternative layouts in the project, the analytic hierarchy process will be the more effective multiple objective decision making technique.

2.10. Case Study: Application of the Systematic Layout Procedure

As the completion of this project will be done according the steps and processes of the SLP, it is important to know whether the practical applications of the SLP have been successful in the real-world.

The SLP has been applied to a can production company in Ethiopia. An article presenting a real-world application of the SLP is titled “*Production Floor Layout Using Systematic Layout Planning in Can Manufacturing Company*”, by A.P. Singh and M. Yilma published in 2013 in the IEEE.

Singh and Yilma intended to apply the SLP procedure in solving the can production shop floor layout problem. The problems of the production shop floor included:

- ❖ Bottlenecks were identified within the production department.
- ❖ The production shop floor having multiple departments and workstations within the facility has parts and materials flowing between them in no order or according to any fixed system.
- ❖ It became evident that materials are traveling unnecessary distances and the buffer areas required to support production are not strategically positioned to supply the workstations’ demands efficiently enough.
- ❖ The traveling costs for materials are increasing due to additional and more expensive equipment required to transport it.
- ❖ An increase in department labour was required to attempt to increase the throughput of the department by transporting the materials through the system in a shorter amount of time.
- ❖ Labour costs were getting too expensive due to a continuous increase in the requirement for labourers to transport the products.

The steps followed by Singh and Yilma according to the SLP to successfully complete the project were:

Step 1: All existing data was gathered regarding the systems and processes, space available and product characteristics.

Step 2: The flow of the materials for the can to be produced was determined and graphically presented.

Step 3: The relationship between resources is determined and discussed by means of:

- ❖ A relationship chart,
- ❖ a process flow chart,
- ❖ an activity relationship worksheet, and

- ❖ a dimensionless block diagram.

Step 4: A relationship diagram, or a string diagram, was set up to illustrate the necessity and volume of the flow of materials between workstations.

Step 5: A space requirement table for all the components of the final products and of the workstations within the department was developed by analysing the space required with the allowances of all the machinery and labourers.

Step 6: The available space in the production department was determined to be enough for the processes required to take place within the department for the manufacturing of the cans.

Step 7: A space relationship diagram is developed by combining the space requirements and the space available for step 5 and step 6.

Step 8: The modifying constraints were identified regarding the development of alternative layouts.

Step 9: Practical limitations were discussed regarding the project environment. In the case of the production floor problem, existing production floor area could not be expanded for additional space.

Step 10: Alternative layouts were developed. Singh and Yilma developed two alternative layouts within the available space for the production department.

Step 11: The alternative layouts were evaluated according to the extent that the layouts fulfilled the objectives of the project, namely:

- ❖ Total travel distance,
- ❖ total travel time,
- ❖ total travel cost, and
- ❖ back tracking.

To conclude their report on the practical application of the SLP procedure, Singh and Yilma made the following remarks:

- ❖ High volume transport of goods over long distances led to the company being unable to attain the planned production volume.
- ❖ SLP aided in successfully developing two alternative facility layouts.
- ❖ Operation costs are decreased due to the reduced traveling distances and traveling times.
- ❖ Traveling between workstations was minimised.
- ❖ The traveling cost was reduced by using SLP.
- ❖ The safety of the new layouts could be determined beforehand.
- ❖ The total time consumption due to material flow led to an increase in productivity and the overall throughput of the department.

As the abattoir of Kroon's Gourmet Chickens is also viewed as a manufacturing line with its multiple workstations and buffer areas with various materials flowing into, through and from the department, the method applied to the can production plant that led to a successful analysis and completion of the goals set out by the plant to decrease traveling time and cost for the products due to the application of the SLP procedure, leads to the conclusion that the SLP procedure can be applied to the abattoir as well.

2.11. Literature Review Conclusion

The literature review discussed multiple tools and techniques that can be used together in order to analyse the abattoir of Kroon's Gourmet Chickens. The tools and techniques that are available to improve and increase the abattoir's throughput is also discussed and proven to be a reliable and effective way for this application by the case study discussed in paragraph 2.11. Where multiple techniques were discussed for one application, the techniques delivering the best and most reliable results will be used in the project.

Chapter 3

Theoretical Design

The Systematic Layout Planning procedure must be applied to the layout of the abattoir packaging department from the inception of the project to the conclusion with the main objectives of the problem kept in mind at all times. It is therefore important that the objectives be redefined and confirmed with the managing director at Kroon's Gourmet Chickens before the project is started. These objectives become the basis of any argument or reasoning methodology when any solution is being researched or developed.

The current layout of the abattoir as a whole with the main process flows in the respective departments will be analysed and depicted in a flow process chart and an activity relationship diagram. Any processes flowing directly into and out of the packaging department will be identified and categorised according to the severity of influence it has on the processes within the packaging department. The packaging department will be thoroughly analysed using the facilities planning tools and techniques in order to better understand how the processes fit together and to aid in the problem identification process.

During the analysis of the abattoir and the concept development phase, any form of waste according to the eight categories of waste described by Eaton, will be identified and eliminated. The lean thinking approach will be applied to every decision making and planning process during the completion of this project.

The containers, tote pans, which are used currently in the facility will be analysed and defined in terms of its materials, dimensions, advantages, disadvantages and the cost of one container. Material handling techniques will be discussed regarding the tote pans and the products as one unit. The use of conveyors to transport products within the packaging department will be thoroughly researched regarding feasibility and other real world applications of conveyors in abattoirs.

Most importantly, the space required to successfully conduct the necessary processes in the packaging department will be determined by means of a space requirement table and a space relationship diagram. From the labourers up to the equipment used in the department will be analysed and have its space requirements logged. It will then be determined whether the current space available is enough for the entire system's space requirements.

Using all of the tools and techniques, focusing on the objectives of the project and bearing the eight wastes in mind, alternative layout plans will be generated. These plans will focus on achieving the objectives within the smallest space required with allowances for future growth. The layout plans, being at most three alternative layouts, will focus to increase the throughput of the system by means of focus on a high return on capital investment.

A thorough economic analysis will be made on each of the alternative layouts in order to determine the net present value and break-even point of the proposed layout. These results will be included in the evaluation of each alternative. The alternatives will be evaluated and compared to each other using the analytic hierarchy process with various criteria to base the evaluations upon. The best alternative will then be chosen and further analysed and modified to ensure the layout plan fulfils the project objectives to its fullest extent.

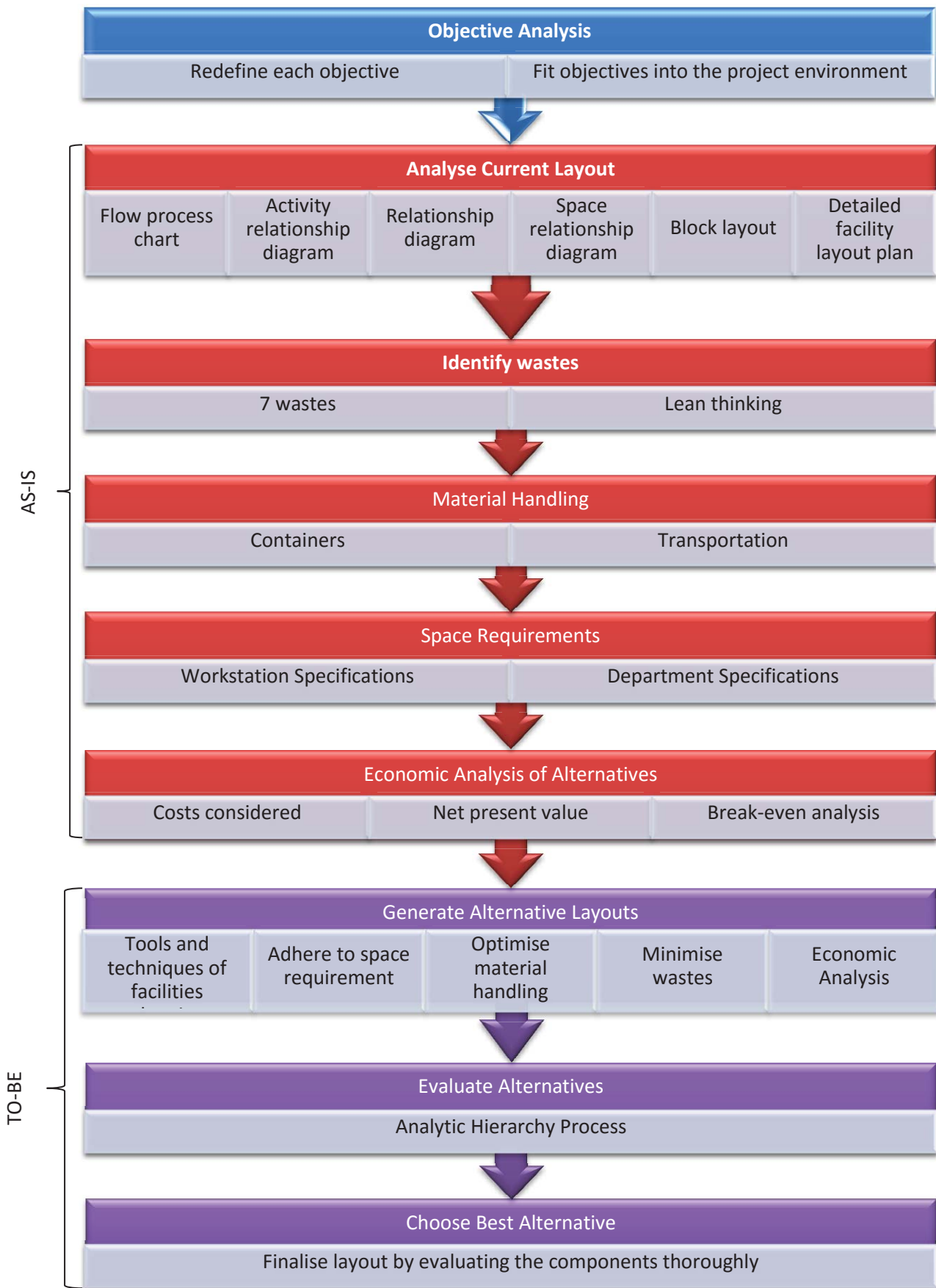


Figure 5: Project Conceptual Design

Chapter 4

Analysis of Current Layout

4.1. Project Environment

The project environment must be thoroughly assessed and analysed in order to determine its stability regarding any internal and external influential factors. Some factors may not seem as a highly influential factor at first, but may after inspection prove to be quite an important factor to include in the analysis of the environment. Thus, all factors will be included in the scope of the analysis and from thereto ranked and classified.

4.1.1. Location of the Farm



Figure 6: Kroon's Gourmet Chickens

The farm is located in Wildebeesthoek, in the De Wildt area on the way to Brits from Pretoria on the R513. There is ample space available on the farm itself for any construction projects of new facilities. The problem arises when production must be halted, even if for a day or less, to move or adjust any part of the system, while complying with all the health and safety regulations at the same time.

4.1.2. Abattoir Environment

The abattoir environment, the red rectangle as illustrated in Figure 7, is very accessible, in the sense that it is centrally located regarding the inputs and outputs of the abattoir. The management offices are located on the southern side of the abattoir with the truck off-loading deck accessible by the main road on the north-eastern side. The abattoir itself with its cycles and product flow will be illustrated and discussed in detail in the As-is Analysis section of this project. As the throughput requirement of the abattoir has generally increased over the years, additions and modifications to the abattoir have been made 'on the go'. No proper space requirement forecasts were made at any point in time in the past, which makes any facility expansions a difficult task. The environment of the abattoir is completely stable and complies with all the laws and regulations regarding abattoirs in South Africa.



Figure 7: Abattoir Arial View

4.1.3. Personnel Involved

Personnel involved in the workings of the abattoir range from illiterate to tertiary educated employees. Proper communication systems are implemented in the abattoir between employees. Employees are represented by a workers union.

4.2. Current Processes of the Abattoir

The stunned, bled and boiled chickens are transported to the defeathering machines via rail hooks hanging on a chain conveyor. After the chickens are defeathered, they are opened up at the abdomen, have the gizzards removed, crop pulled out and are automatically beheaded by a hook on the conveyor in the EV Room. The products are inspected and washed in the EV Room before it is sent to the air chillers, via the rail hooks, in order to rapidly cool down the temperature of the chickens before processing and packing. In the packaging department, the chickens are weighed manually in order to determine whether the chickens' weight are according to the customers' specifications. The optimal weight for a chicken to be packed whole is between 1.2kg and 1.4kg, as preferred by customers. Chickens that weigh more or less than these specifications are portioned. A fraction of the chickens is sent to the Value Adding department in order to marinate and spice whole and portioned chickens for various clients. The chickens are packed whole, portioned and as value added products, the products are then stored in the freezers and the dispatch cold room awaiting transportation to the customers at the various loading bays.

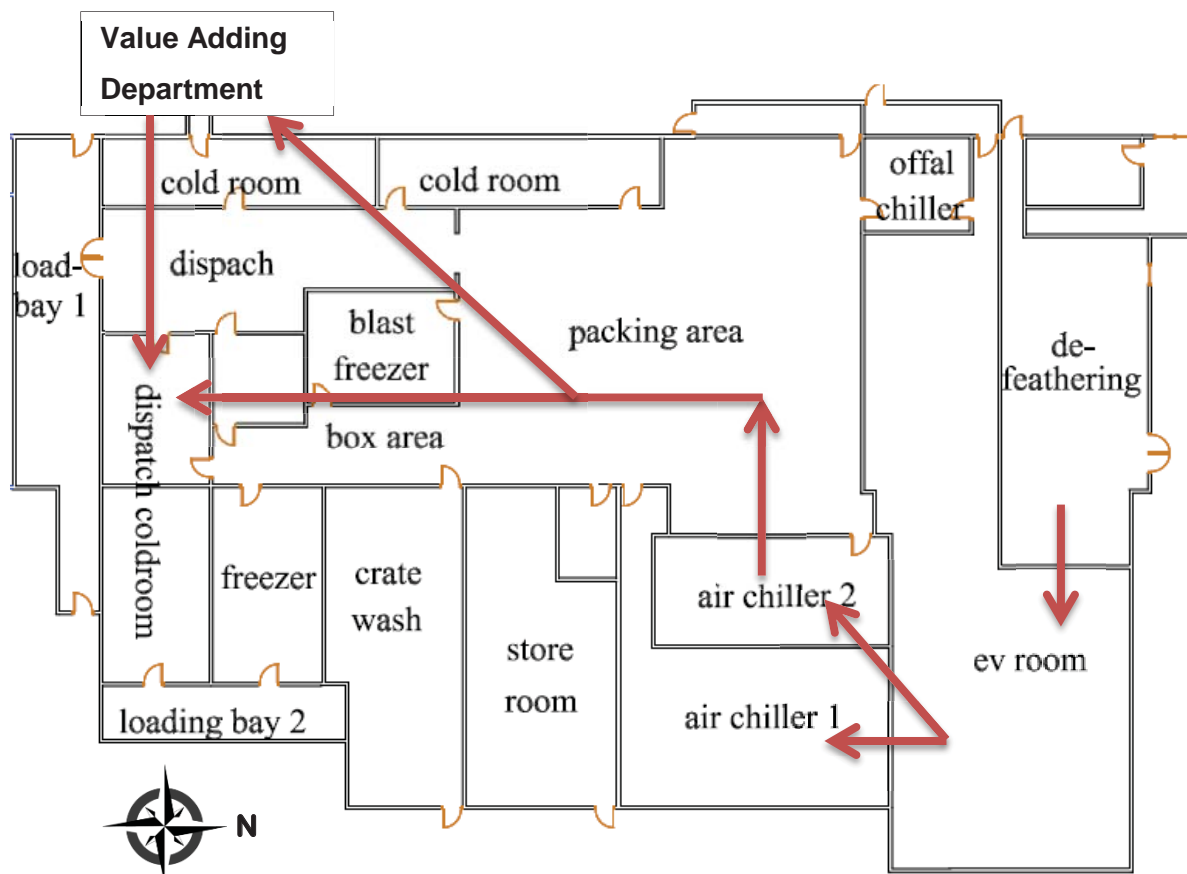


Figure 8: Packaging Department Process Flows

4.3. Charts, Diagrams and Schematics to Analyse Current Layout

The current layout that will be analysed regarding the packaging department will include all processes that are conducted after the products exit the chillers and enter the packaging department via the entry chute, up to where the products are transported to the dispatch area.

4.3.1. Flow Process Chart: Current Layout

The flow process chart depicts the processes applied to whole chickens as the products enter the packaging department from the chillers.

From the chillers, chickens can follow three different routes to be processed. The first is where chickens are processed and packed whole. The second is where the chickens are portioned and then packed. The third process applicable to the chickens is where the chickens are sent to the value adding department to be spiced or marinated as whole chickens or portioned pieces. The difference in the processing times in the three processes is only at the workstations for processes one and two. Process three has a larger travel distance to cover, as the chickens must be transported from the packaging department to the value adding department through the cold rooms and back again to the loading bay cold rooms. The value adding process takes a bit longer than the normal processing of the chickens as well, but the largest portion of the time difference is due to the transportations towards and from the value adding department through the cold rooms.

4.3.2. Activity Relationship Diagram

The packaging department activities take place across a variety of service areas within the abattoir. The service areas that will be evaluated are areas that have processes flowing directly in or out of the packaging department.

- ❖ Entry Chute: The entry chute is a chute at the air chillers that enters directly into the packaging department where workers receive the fresh, cooled produce to weigh it and send it to the different processing systems.
- ❖ Packing Area: The packing area is the main area of operations of the packaging department. After the chickens are weighed, they are sent to the various workstations which process different weights of chickens. Whole chickens that are packed have a desired weight of 1.2kg to 1.4kg. Chickens larger than 1.4kg are portioned within the packaging department or are sent to the value adding department to be portioned and processed there. The chickens that are smaller than 1.2kg are usually sent to the value adding department to be portioned and processed. The packing area's workstations require to be resupplied with packing equipment and empty tote pans. The

waste bins have to be emptied constantly. It is extremely important that the packing area be uncontaminated by any substance at all times. There is no free air flow into the department. Sanitation and hygiene check points are available all across the department.

- ❖ Tote Pan Bay: The tote pan bay is the buffer area from where empty tote pans are sent to the various workstations and the entry chute which requires empty tote pans. The tote pan bay is resupplied from the tote pan washing area on a constant basis.
- ❖ Value Adding: The value adding department is where whole chickens and chicken portions are spiced or marinated and packed as products with additional value added for various customers' special requests.
- ❖ Cold Rooms: The cold rooms are cooler rooms where products are stored before being shipped to the dispatch area or before being processed at the various workstations in the event that the packaging department is behind schedule and needs additional space to temporarily store the products.
- ❖ Loading Bay: The loading bay with its coolers is the final buffer area before the products are shipped to the customers via Kroon transportation or the customer's own transportation.
- ❖ Waste Disposal: The waste disposal area is where the waste of workstations is being collected to be transported out of the facility to the waste bin. The waste disposal area is kept clean and hygienically suitable at all times.

A fact important to take note of, as can be seen in Figure 9, is the undesirable closeness rating with the medium frequency of use allocated to the relationship between the value adding and the cold rooms. This is due to the fact that products from the value adding department sometimes spill some of its contents. As the contents contains various spices to which people are allergic to, and the cold rooms contains clean, processed and packed chickens, various suppliers and health regulations request that the chickens in the cold rooms be disposed of. These chickens are usually either disposed of, or sold to the public and employees at a break-even point or a loss to the company, depending on the time of day and the need of sales by the employees. The chickens may also be sent to the value adding department to be processed, if there is an existing demand for chickens to be processed in the value adding department.

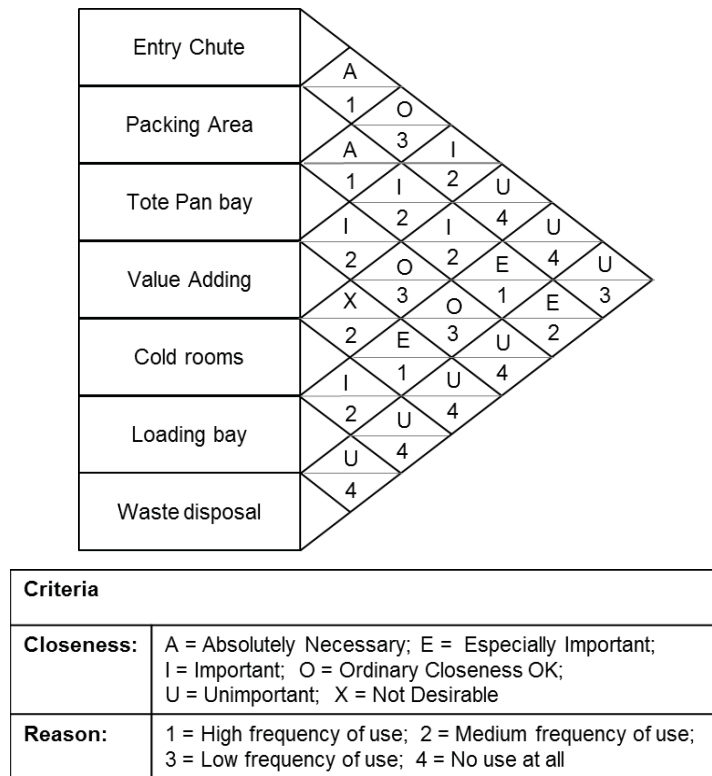


Figure 9: Activity Relationship Diagram of Packaging Department Activities

4.3.3. Block Layout and Space Relationship Diagram

Firstly, the block layout depicts a very unique facility layout regarding such a vital department of the abattoir. This is due to the fact that the abattoir has expanded over the years at such a steady pace, that an entire re-layout of the facility was not possible. Additional structures were added on a regular basis. And as the abattoir is not able to halt its processes for one single day of operations, whatever work needed to be done had to be done over weekends.

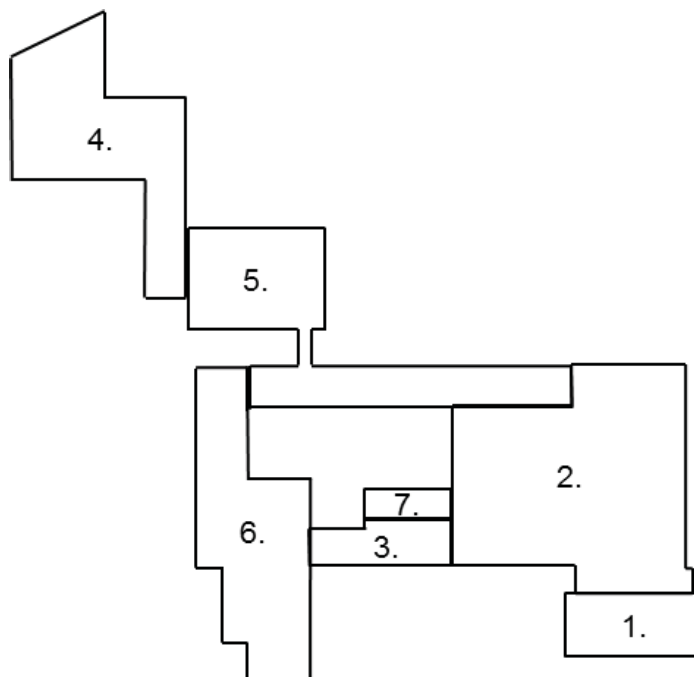
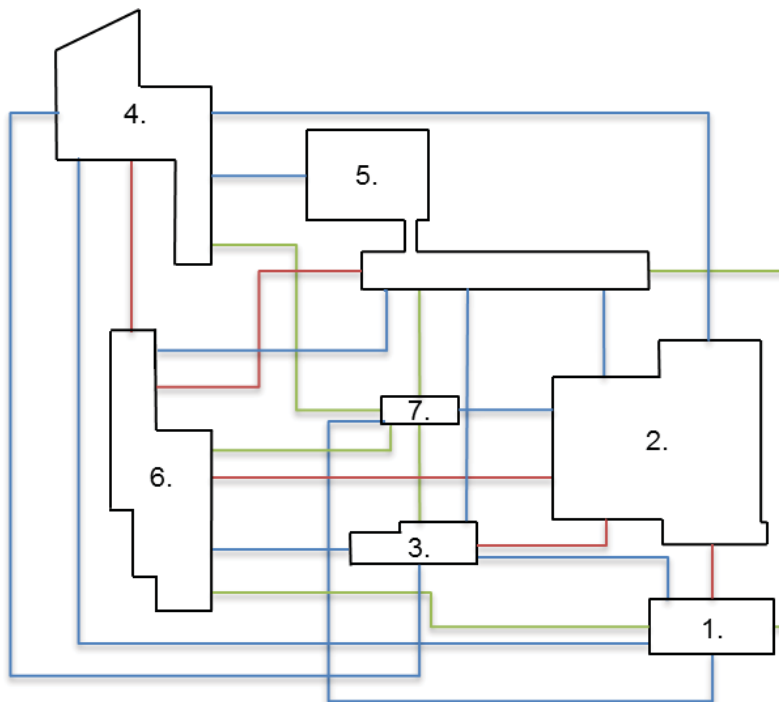


Figure 10: Block Layout of Functional Areas in the Packaging Department

Table 7: Current Space Requirements of Functional Areas

	Function Area	Area (m ²)
1	Entry Shute	7.5
2	Packing Area	253.57
3	Tote Pan Bay	28.29
4	Value Adding	140.83
5	Cold Rooms	134.67
6	Loading Bay	51.56
7	Waste Disposal	15.64

The space relationship diagram depicts the flow of products and materials within the packaging department between the functional areas, as illustrated in Figure 11. The green, blue and red lines indicate the flow rate from low to high.



Legend:




Line	Flow
	Low rate (Less than 20% of flows)
	Medium rate (20-50% of flows)
	High rate (more than 50% of flows)

Figure 11: Space Relationship Diagram of Functional Areas in the Packaging Department

4.3.4. Current Workstations' Material Flow

The workstations as it is in the packaging department are displayed in Figure 12. The chickens from the hanging link conveyor are put onto the scales by three workers. The chickens are manually weighed by the three workers and transferred into the various tote pans according to their weights, as required by the different workstations. The full tote pans of chickens to be processed are delivered at the various workstations which require chickens to process when needed. Each workstation set has one worker to ensure that the

workstation set always has chickens to process. That is six workers using the aisles at random times transporting full and empty tote pans back to the scales.

The workstation sets require empty tote pans in order to store and transport the processed and packed chickens. These empty tote pans are delivered to the workstation sets by another three employees at random times as required by the workstation sets.

Finally, the full tote pans containing the processed and packed chickens are transported to the dispatch station awaiting pickup by the customers. These crates are carried by a worker to the dispatch coolers as soon as the tote pan contains enough chickens, which is approximately 20 chickens, depending on the size of the chickens. The chickens required by the value adding department are delivered from the workstations' available chickens as needed by the department.

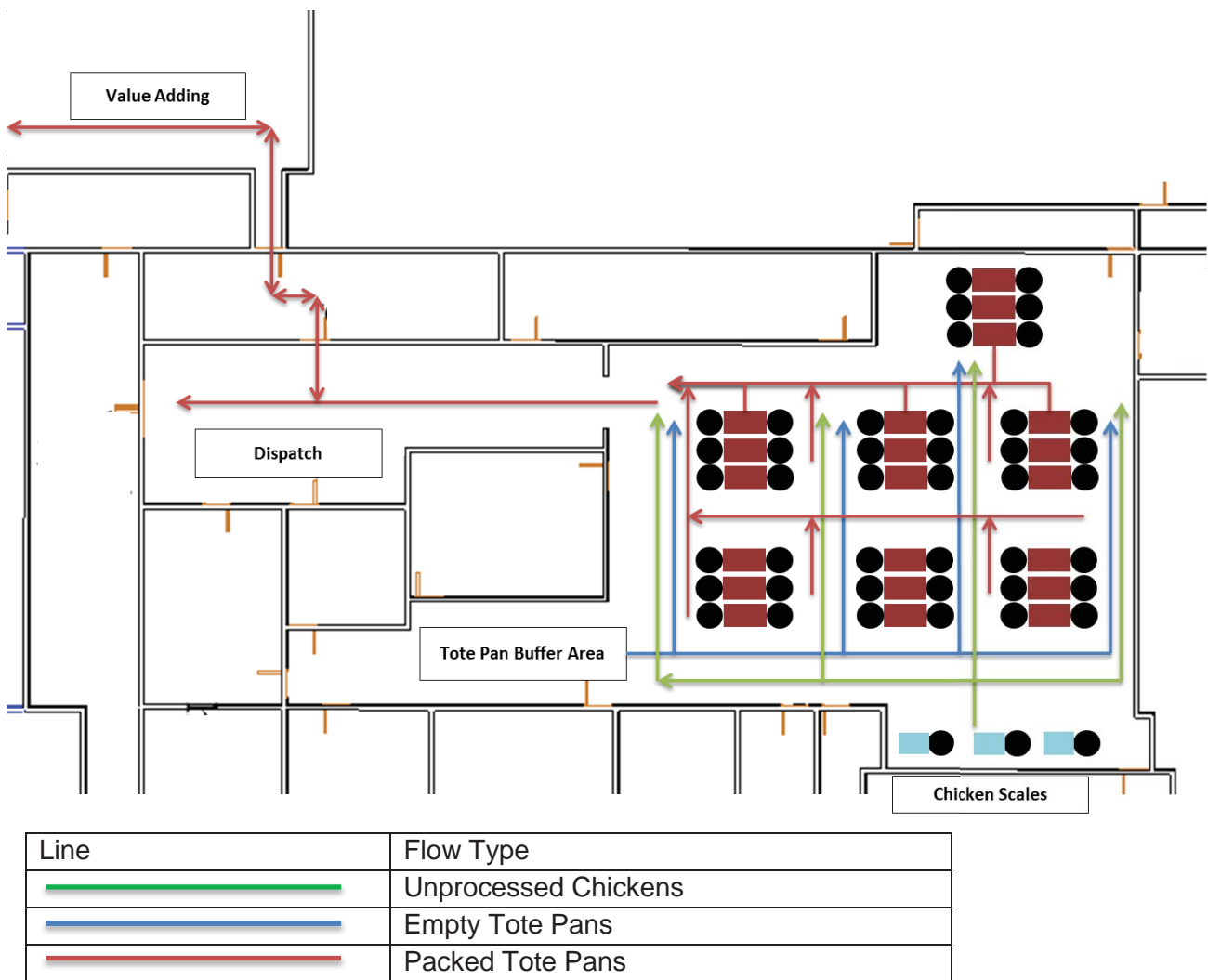


Figure 12: Current Layout Material Flow

4.4. Space Requirements of the Packaging Department

The workstation space requirements for each worker adhere to the specifications set out in the literature study. As there is no moving machinery within the department, the operator ingress and egress aisle requirement of 76cm is sufficient in order to allow workers at a workstation to continue with their work without the disruption of a passing employee. Each

workstation operating surface provides sufficient space for the materials required to pack the chickens. Each workstation's area is approximately 2m². With 21 workstations, this adds up to 42m². The aisles' area adds up to 151m² within the packaging department. The aisles between the workstation sets are not wide enough for the flow of tote pans in opposite directions. One of the two aisle users will have to wait for the aisle to clear in order to use the aisle, which causes a lot of delays in the delivery and transportation of the chickens to the dispatch location. With the packaging area consisting of 250m², there is enough space left for improvements on the product flow within the department.

4.5. Identification of the 7 Wastes

4.5.1. Waiting

Waiting for parts or elements to arrive at a process is considered a waste as defined by Ohno (2011). In the packaging department, multiple workstations have to wait for empty tote pans to be delivered to the station. Workstations have to wait for tote pans which are packed to be removed from the workstation. This form of waste accumulates to a lot of time that could have been used to deliver products.

4.5.2. Overproduction

Producing more products than are required by the customer/s is not a waste that is found in the packaging department of the abattoir. The abattoir only produces fresh products as customers request the products. Kroon's Gourmet Chickens do not sell frozen chickens, therefore the cost of overproduction will be very high.

4.5.3. Rework

Undertaking a task more than once due to incorrect processing the first time, is considered a waste. In the packaging department's current layout, the Rework waste may cost the department a lot of time, effort and products if not managed carefully. The only event that will cause the department to discard products and to resupply the discarded products, is when products from the Value Adding department is being transported back from the Value Adding department through the cooling room into the store rooms to await transportation to customers, and the value added products have spilled and contaminated the chickens in the cooling room. Most of Kroon's Gourmet Chickens have customers with very strict contamination policies due to allergies of customers.

4.5.4. Motion

Movement of human beings, whether contributing or not contributing to the completion of the process, is considered a waste, which is ever-present in the packaging department. The packaging department has no form of automation in any of its processes. All of the work done is due to movement of workers in the department, contributing and at times not contributing to the completion of the processes.

4.5.5. Transport

Movement of equipment, information and/or materials is a waste that is present in the packaging department. The following movement is being done in the department:

- ❖ Movement of the empty tote pans from the from the buffer areas to the workstations.
- ❖ Movement of the packed tote pans from the workstations to the cooling rooms.
- ❖ Movement of information to signal when tote pans and products must be transported.
- ❖ Movement of the products through the department and the cooling room to the Value Adding department.
- ❖ Movement from the Value Adding department back through the same cooling room to the storage area to await transportation to the customer.

4.5.6. Processing

Undertaking any activity that is explicitly not required by the customer or regulations does not take place within the packaging department, except when an order must be reworked.

4.5.7. Inventory

Costs of holding, managing, storing and disposing of products are processes which take place throughout the packaging department. The costs of holding and storing are costs which are kept to a minimum. The managing and disposing of products are costs that are relatively high. Every time a chicken is dropped onto the floor of the department, it must be disposed of, due to contamination of the product.

4.5.8. Talent

This is a waste of expertise by human beings by expecting them to complete tasks that would be better undertaken by another person or not done at all. This waste is not present in the packaging department as all employees in the department are qualified and remunerated according to the work conducted by each individual. No over-qualified personnel are employed in a position where menial labour is expected.

4.6. Analysing the Lean Thinking approach in the Packaging Department

In Womack and James's book, *Lean Thinking: Banish waste and create wealth in your corporation* (1996), the five lean principles were discussed, as well as previously in the literature review of this report. In terms of these five principles, the 'Value' from the customer's perspective regarding the products delivered is quite thoroughly defined and maintained at Kroon's Gourmet Chickens. The company strives to deliver the freshest products on time to all of its customers. Any contaminated products due to contact with Value Adding department substances or unclean surfaces are disposed of immediately.

The value stream to deliver the current value to the customers is properly illustrated, maintained and constantly improved upon. The system is mapped out, with proper communication channels between the departments responsible for the value of the final products.

The processes in the facility is upgraded and improved upon on a continuous basis. New technology is being tried and tested to see which is most effective on increasing the throughput of the abattoir as a whole. The aim of the facility is to have a system that flows continuously without any external influences disturbing this system.

Demand for the products on any given day is forecasted at least four weeks prior to the day of operation. The activities in the abattoir are triggered by this demand, it is 'pulled' by the customer.

And, finally, aiming for perfection on any given day is the current goal of all of the managing directors at Kroon's Gourmet Chickens. The managing directors maintain a continuous awareness on all levels of employees that perfection is the standard striving towards. When striving for perfection, it would be difficult to produce products that are not more than satisfactorily to the customer.

Kroon's Gourmet Chickens applies the Lean Thinking approach to all of its processes, whether intentionally or unintentionally.

4.7. Analysing Current Material Handling Tools and Techniques

The current material handling tools used in the processes of the packaging department are very basic and easy to use.

Table 8: Current Material Handling Tools and Techniques

Material	Moves	Methods
Empty Tote Pans	<ul style="list-style-type: none"> - Empty tote pans are moved from the tote pan bay to the designated workstations which require the pans. - Empty tote pans are moved from the loading bay to the tote pan washing area in the event that customers have their own crates. 	<ul style="list-style-type: none"> - Empty tote pans are fairly easy to carry by hand in sets of 5, which is within ergonomically acceptable weights.
Packed Tote Pans	<ul style="list-style-type: none"> - A full tote pan is carried to the cold room from the workstations to the cold rooms, waiting to be portioned. - Full tote pans are carried from the weighing section at the entry chute to the workstations. - Full tote pans are transported from the workstations to the dispatch cold rooms. - Full tote pans are carried to the value adding department for further processing, and back to the dispatch cold rooms. 	<ul style="list-style-type: none"> - Full tote pans are usually carried by hand. The weight of a full tote pan is at most 20kg per pan, which is an ergonomically acceptable weight to carry it. - Heavier tote pans or stacked full tote pans are dragged with a hook attached to the bottom crate.
Whole Chickens	<ul style="list-style-type: none"> - Whole chickens are transported onto the scale, before being sorted in tote pans at the station. - Whole chickens are lifted onto the workstations from the tote pans. - Whole chickens are lifted into empty tote pans and transported to various locations. - Whole chickens are packed and sealed at the workstations. 	<ul style="list-style-type: none"> - Whole chickens are always moved by hand.
Portioned Chickens	<ul style="list-style-type: none"> - Portioned chickens are packed and sealed at the workstations into various cuts and quantities. - Portioned chickens are moved from the workstation into empty tote pans awaiting transportation to various locations. 	<ul style="list-style-type: none"> - Portioned chickens are moved by hand into packages and then into the empty tote pans.
Waste Products	<ul style="list-style-type: none"> - Waste products are put into waste bins at workstations. - The waste bins are transported to the waste disposal area in the packing area. 	<ul style="list-style-type: none"> - Waste products are placed into the bins by hand. - The waste bins are carried by hand to the waste disposal area.

The majority of materials and products are transported by hand. The employee responsibility distribution varies within the department. There are 42 workers positioned at the workstations to process and package the chickens in the packaging department. There are approximately 17 employees who fulfil supporting positions within the department, like transporting the tote pans and weighing the chickens. The 17 employees are shared with other departments in the abattoir as well.

4.8. Throughput Analysis of the Current Layout

The throughput of the abattoir is determined by the amount of chickens that are stored in the cold rooms and the dispatch area as finished products. The chickens processed and packaged per hour as whole chickens and portioned chickens are counted. The proportion of processed products in the packaging department regarding whole and portioned chickens, is 80% whole chickens and 20% portioned chickens. These values may change depending on the daily demand by the various customers.

Table 9: Throughput of the Current Layout

	Number of Workers	Throughput
Whole	34	2727
Portioned	8	384
Total	42	3111

4.9. Economic Analysis of the Current Packaging Department Layout

The objective of this study is to determine whether an alternative layout of the packaging department would be more profitable for Kroon's Gourmet Chickens. As discussed, the only costs that would be included in the economic analysis are the labour, acquisition and maintenance cost and the amount of sales made on products. The revenue from sales will not be included in the analysis of the layouts, as it will not aid in providing an accurate representation of the advantages of the layouts. However, the throughput will be used as a basis to represent the amount of sales made, as all products produced are sold every day. The monetary value of R1 will be used to represent the profits made by one chicken, with the subtraction of all the expenses to get a clear, basic indication of the difference in the throughput advantages of the different layouts.

Table 10: Economic Analysis of the Current Layout

Capital Type	Description	Amount
Labour Cost	The labour cost is the total cost of the employees' wages that is working in the packaging department. There are currently a total of 42 employees working in the packaging department. The average daily wages of an employee is R150 a day.	R138 600 per month
Acquisition Cost	There is no acquisition cost with the facility as it is.	None.
Maintenance Cost	The maintenance cost present in the current facility is an average of R3000 per month per workstation. There are currently 21 workstations.	R63 000
Profit due to sales	With a current throughput of 3111 chickens per hour, 22 days in a month and 8 hours in a working day, and profit value of R1 per chicken.	R345 936

4.10. Analysis of Processes and Identification of Improvement Areas

The current layout has a throughput of 3111 chickens per hour. The throughput must be increased as this is the lowest throughput of all the departments of the abattoir.

Problem areas were identified with the current layout where improvement can be made:

- ❖ Cold rooms: The value added products must be transported back through the cold room to the dispatch area. In the event of contamination with other clean products, these products' profits are considered null to the company. A solution must be found in order to avoid such contamination.
- ❖ Packaging area: Employees transport empty and full tote pans by hand across the department whenever needed and at random. There is continuous congestion at the doorways leading to the dispatch area and the value adding department.
- ❖ Packing area: Time is wasted when employees wait for full tote pans to be delivered to the workstations and when they wait for full tote pans to be removed from the workstations.
- ❖ Whole department: When products are dropped, the profits of the products are considered null.

- ❖ Whole department: Fifteen (15) potential cross flow delays are present within the department between chickens, empty and full tote pans.

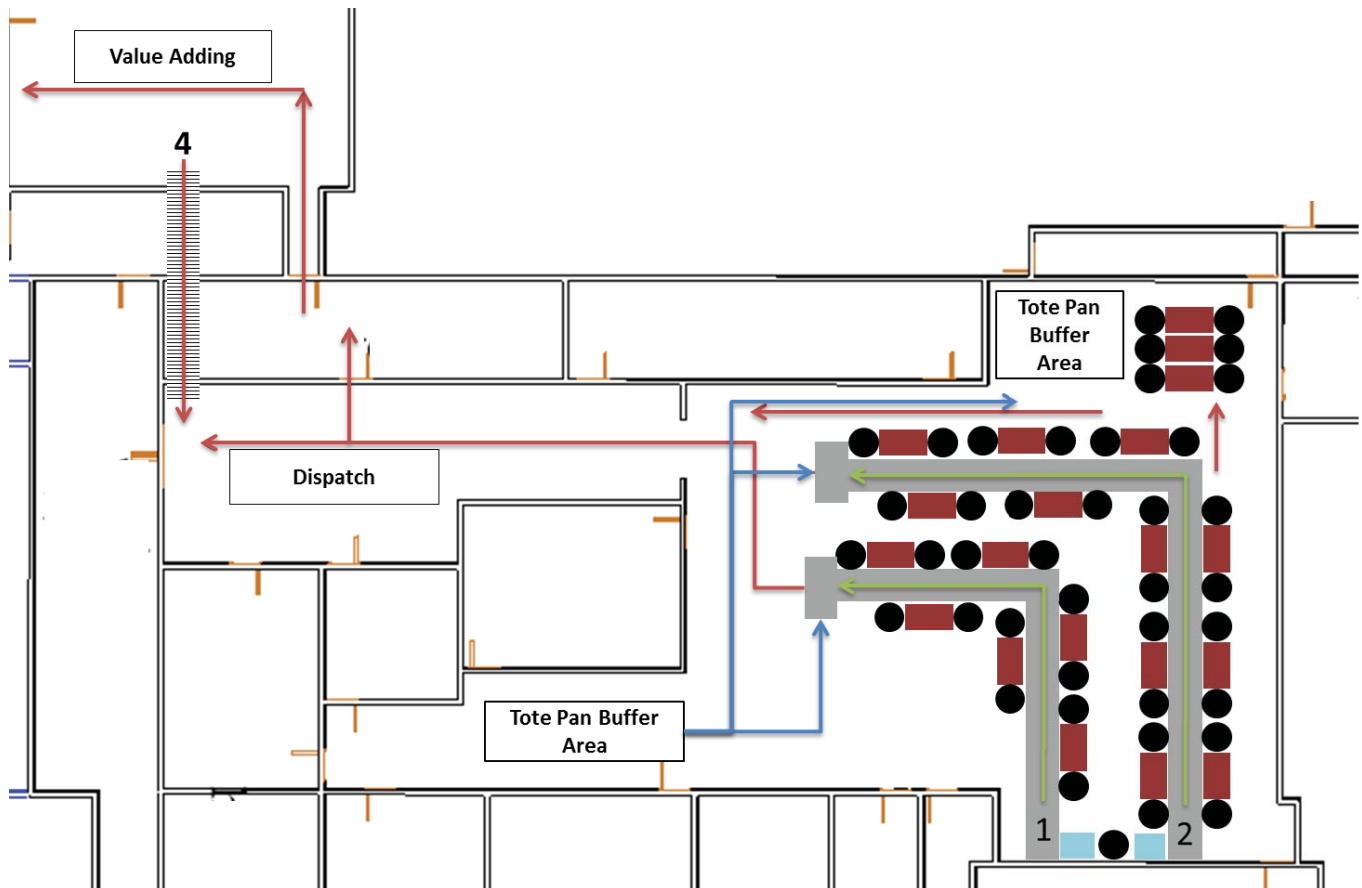
Chapter 5

Conceptual Designs

5.1. Alternative Design: Automated Layout by means of Conveyors

5.1.1. Process Description of Layout

The chickens are dropped onto the automatic scale by a hook that removes the chickens from the hanging conveyor as it passes by the hook. The scale then weighs and shifts the chickens either left or right onto conveyor one (1) or conveyor two (2), depending on the programming of the scale according to the required weights by the conveyor lines. Conveyor line one processes the smaller chickens for customers. Conveyor line two is used to process the larger chickens and transfers some of the chickens to portioning stations as they require the products. The processed and packed chickens are then transferred back onto the conveyor where a worker transfers the chickens from the conveyor to the tote pans at the end of the conveyor lines. As soon as enough tote pans are full, a stack of four to six tote pans, the stack is dragged via hooks by a worker to the dispatch cold rooms. This minimises the flow of workers with single crates from workstations that causes congestion in the aisles. Chickens required by the value adding department are collected from conveyor line two, which are the heavier chickens. Damaged chickens by either conveyor line one or two are transported to the value adding department or are portioned, depending on the demand for the day. The conveyor buffer areas are supplied with empty tote pans when needed from the tote pan buffer area, and when a full stack of tote pans are not to be delivered to the dispatch station so as to prevent cross flow obstructions. The workstation set next to conveyor line two only processes chickens to be portioned. As this workstation set uses tote pans to transport chickens from conveyor line two to the workstations and to the dispatch cold rooms from the workstations, a tote pan buffer area is created next to the workstation set. No additional workers are needed to transport tote pans from this buffer area to the workstation set. The materials required by the workstations are to be stocked before each shift and/or production run. Conveyor line 4 is installed as a motorised roller conveyor from the value adding cold rooms to the dispatch area. A hall will be built in order to isolate this conveyor from the cold room and the forces of nature, in order to prevent contamination from value adding substances to the products stored in the cold rooms.






Line	Flow Type
	Unprocessed Chickens
	Empty Tote Pans
	Packed Tote Pans

Figure 13: Automation by Means of Conveyors

5.1.2. Space Requirements Adherence

Figure 13 is drawn on scale with the actual lengths and widths of the conveyors and the space requirements of the workers. There is space available for an additional workstation set next to the tote pan buffer area in the event that more portioned workstations are needed. A maximum of six more workers can be added to aid with the portioning of chickens. The clearance in the aisles required for workers to pass each other and stationary objects is sufficient, as required and discussed in the literature review.

5.1.3. Flow Process Chart: Conveyor Layout

The total time in minutes calculated for the processing of the products, is for an average of ten chickens processed. The flow process charts for the conveyor layout can be analysed in Appendix B.

5.1.4. Optimised Material Handling

Table 11: Optimised Material Handling by the Conveyor Layout

Materials	Moves	Methods
Empty Tote Pans	- Transported from the buffer areas to the workstations.	- Carried by hand or dragged by a hook connected to the bottom tote pan.
Packed Tote Pans	- The full tote pans are transported from the buffer areas to the cold rooms and the dispatch area	- Dragged by a hook connected to the bottom tote pan.
Whole Chickens	- The whole chickens are transported from the scale to the designated workstations, and then to the buffer area.	- The chickens are shifted onto the conveyor by the scale and transported to the workstations via the conveyors. - The packaged chickens are transported again via the conveyor to the tote pans at the end of the conveyor.
Portioned Chickens	- The chickens to be portioned are transported to the additional workstation group.	- Workers collect chickens from the conveyor, transports them in tote pans and delivers them to the designated workstation.
Waste Products	- Waste products are put into waste bins at workstations. - The waste bins are transported to the waste disposal area in the packing area.	- Waste products are placed into the bins by hand. - The waste bins are carried by hand to the waste disposal area.

5.1.5. Minimised Wastes

A lot of wastes are eliminated due to the installation of conveyors within the department.

Table 12: Minimised Wastes in the Conveyor Layout

Waste	Improvement / No Improvement
Waiting	<ul style="list-style-type: none"> - Workers do not have to wait for chickens to be sent to workstations to process and pack it. - The empty tote pans are delivered to each workstation before the last empty tote pan is used.
Overproduction	No improvement.
Rework	- No rework is needed in the department, as the contamination of products in the cold room by the value adding department's products is no longer possible.
Motion	<ul style="list-style-type: none"> - The workers' movements in order to move the chickens from the tote pans onto the workstation is minimised by the closeness of the conveyor to the workstations. - There are no movements by most of the workers to prepare and transport the empty and full tote pans.
Transport	<ul style="list-style-type: none"> - Transportation of chickens to workstations is fully automated with a very little probability in a delay. - Transportation of full tote pans to the cold rooms are not random, and with minimised traffic flow.
Processing	- The processing of the chickens is much faster at the workstations due to the continuous flow of products close at hand and the ease of finishing the process by returning the packaged chicken to the conveyor.
Inventory	- The inventory of the empty tote pans at the top workstation set decreases traffic and delays.
Talent	No improvement.

5.1.6. Throughput Improvements

In comparison to the current layout of the packaging department, the throughput is increased due to the lowered risk of aisle congestion and cross flow delays. Travelling distances of the products are minimised due to the conveyors present in the proposed layout.

Regarding delays due to potential cross flow obstructions of products and equipment, where the current layout has fifteen potential obstruction areas, this proposed layout has only two potential areas, where the empty tote pans' transportation route crosses the full tote pans on route to the dispatch area from the full tote pan buffer area at the buffer areas at the end of

the conveyor lines. One of these cross flow point's traffic is minimised by a buffer area next to the workstation set, which is to be stocked before each shift or production run.

Various travelling distances are eliminated and dramatically decreased by the conveyors and the grouped transportation of full tote pans. The proportion of processed products in the packaging department regarding whole and portioned chickens is still 80% whole chickens and 20% portioned chickens. These values may change depending on the daily demand by the various customers.

Table 13: Throughput of the Conveyor Layout

	Number of Workers	Throughput
Whole	31	4105
Portioned	8	485
Total	39	4590

5.1.7. Economic Analysis of Conveyor Layout

Table 14: Economic Analysis of the Conveyor Layout

Capital Type	Description	Amount
Labour Cost	There are currently a total of 39 employees working in the packaging department. The average daily wages of an employee is R150 a day.	R128 700
Acquisition Cost	The acquisition cost for the conveyors are, according to Bill Bastian, approximately R6000 per meter, with an installation cost of 15% of the conveyor's cost. With 62m of conveyor to be installed, a hall to be built and an automatic scale to be acquired of R120 000.	R587 800
Maintenance Cost	The maintenance cost present in the current facility is an average of R3000 per month per workstation. There are currently 10 workstations. The maintenance cost per month is R1250 per meter of conveyor.	R77 500
Profit due to sales	With a current throughput of 4590 chickens per hour, 22 days in a month and 8 hours in a working day, and profit value of R1 per chicken.	R13 840
Profit after first month	The monthly profit after acquisition expenses are covered	R601 604

5.2. Alternative Design: Alternative Material Flow

5.2.1. Process Description of Layout

The workstations are positioned in two linear sets so as to minimise any redundant and cross flow between workstation groups within the department. The weighed chickens are transported via empty tote pans from the three workers who manually weigh the chickens to the workers positioned on the outer edge of the workstation sets. The workers transfer the chickens onto the workstation where the worker on the inner edge of the workstation set can process and pack the chickens as well. The chickens are delivered to the workstations when signalled or when the workers transporting the chickens observe that the workstation's inventory is nearly depleted. The workers on the inner edge of the workstation sets, transfers the packed chicken into tote pans which is transported by another worker to the full tote pan buffer area as soon as the crate is full. Empty tote pans are transported continuously from the tote pan buffer area in stacks to workstations when signalled by various workstations. The full tote pans are transported with hand trolleys or are dragged on the floor with hooks attached to the bottom crate to the dispatch area.

Chickens needed by the value adding department are collected directly from the scales and transported on a route following the outer edge of the workstation sets. Processed products from the value adding department are transported back through the cold rooms after being thoroughly sealed and checked in the value adding department so as to prevent contamination by the fresh products being stored in the cold rooms.

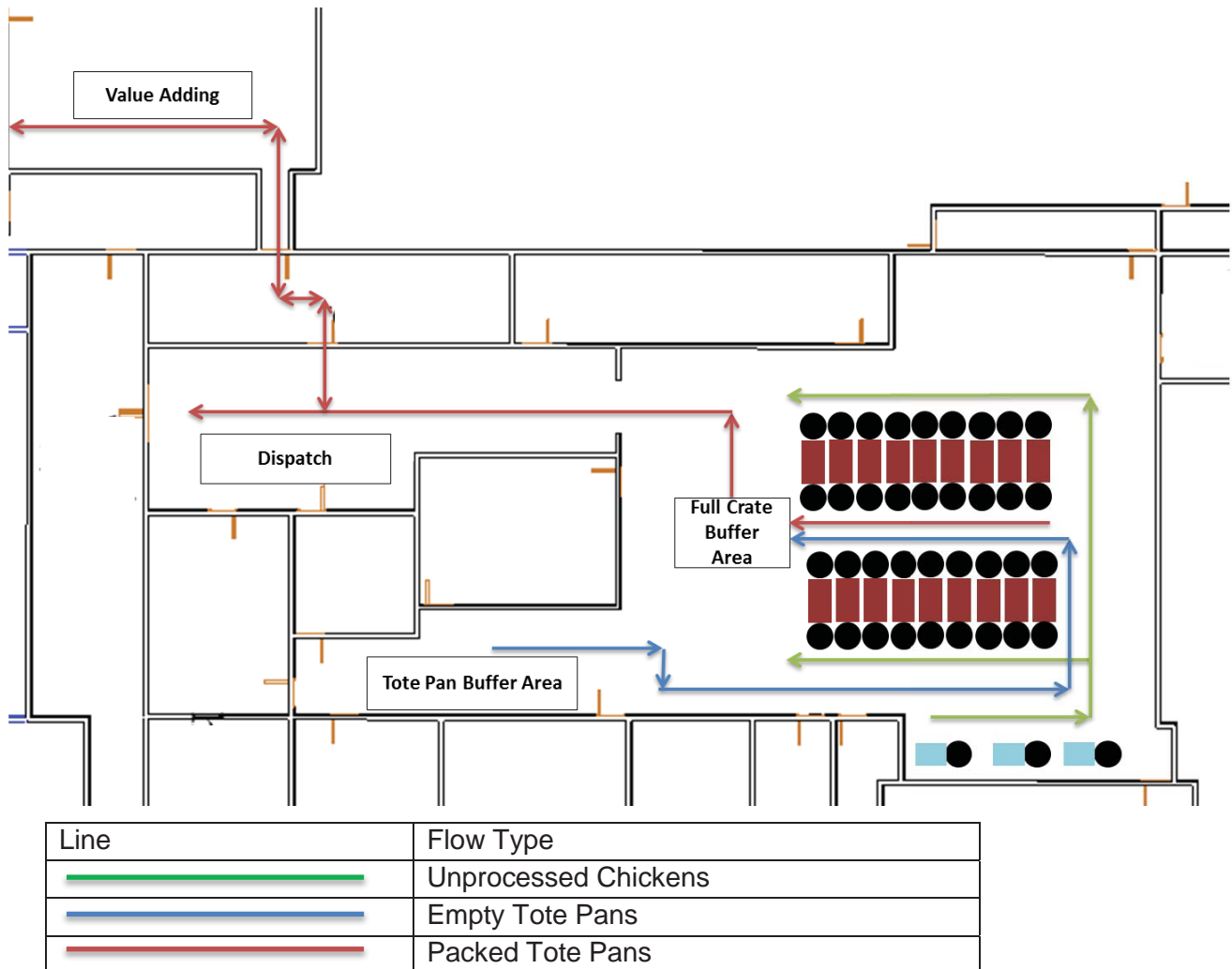


Figure 14: Alternative Material Flow Layout

5.2.2. Space Requirements Adherence

Figure 14 is drawn on scale with the actual lengths and widths of the workstations and the space requirements of the workers. There is space available for additional workstations to be added to the department. A more thorough investigation in the flow rate of traffic in the aisles would have to be done to ensure that the possibility of delays is still very low.

5.2.3. Flow Process Chart: Alternative Material Flow Layout

The total time in minutes calculated for the processing of the products, is for an average of ten chickens processed. The flow process charts for the alternative material flow layout can be analysed in Appendix B.

5.2.4. Optimised Material Handling

Table 15: Optimised Material Handling of the Alternative Flow Layout

Materials	Moves	Methods
Empty Tote Pans	- Transported from the buffer areas to the workstations with minimal cross flow.	- Carried by hand or dragged by a hook connected to the bottom tote pan.
Packed Tote Pans	- The tote pans are transported to the buffer area from the workstations when full. - The full tote pans are transported from the buffer area to the cold rooms and the dispatch area	- Dragged by a hook connected to the bottom tote pan.
Whole Chickens	- The whole chickens are transported from the scale to the designated workstations, and then to the buffer area.	- The chickens are transferred to the empty tote pans by the workers weighing the chickens by hand, and transported to the workstations. - The packaged chickens are transferred to the centrally located workers and then into the tote pans.
Portioned Chickens	- The chickens to be portioned are transported to the designated workstation group.	- Workers transfer the chickens from the tote pans to the workstations.
Waste Products	- Waste products are put into waste bins at workstations. - The waste bins are transported to the waste disposal area in the packing area.	- Waste products are placed into the bins by hand. - The waste bins are carried by hand to the waste disposal area.

5.2.5. Minimised Wastes

Table 16: Wastes Minimised by the Alternative Flow Layout

Waste	Improvement / No Improvement
Waiting	<ul style="list-style-type: none"> - Waiting time for chickens to be delivered is minimised by the decrease in the probability of a delay in the delivery due to traffic congestion in the department. - The empty tote pans are delivered to each workstation before the last empty tote pan is used.
Overproduction	No improvement.
Rework	No improvement.
Motion	- More movements are needed at the workstations when the workers positioned on the outer edge of the workstations have to transfer chickens onto the workstation where the inner positioned workers can reach it for processing.
Transport	<ul style="list-style-type: none"> - The potential delays in the transportation of any materials within the department is minimised due to the decrease in the probability of a delay due to traffic congestion or collisions. - Transportation of full tote pans to the cold rooms are not random, and with minimised traffic flow. - The transportation of the materials have fixed routes with which workers must adhere to and can get used to, thus improving smooth flow within the department.
Processing	- The processing of the chickens is faster at the workstations due to the continuous flow of products close at hand and the ease of finishing the process by returning the packaged chicken to the waiting tote pans.
Inventory	- The amount of smaller inventory areas is less, which minimises delivery traffic within the department.
Talent	No improvement.

5.2.6. Throughput Improvements

The risk of material flow congestion within the department is substantially lower. The amount of tote pan stacks transported at random times to random locations throughout the department is also minimised. The transportation times for the various workstations are much less than that of the current layout.

The proportion of processed products in the packaging department regarding whole and portioned chickens, is still 80% whole chickens and 20% portioned chickens. These values may change depending on the daily demand by the various customers.

Table 17: Throughput of the Alternative Material Flow Layout

	Number of Workers	Throughput
Whole	29	3175
Portioned	7	400
Total	36	3575

5.2.7. Economic Analysis of Alternative Routes Layout

Table 18: Economic Analysis of the Alternative Routes Layout

Capital Type	Description	Amount
Labour Cost	There are currently a total of 36 employees working in the packaging department. The average daily wages of an employee is R150 a day.	R118 800
Acquisition Cost	There is no acquisition costs related to this layout.	None
Maintenance Cost	The maintenance cost present in the current facility is an average of R3000 per month per workstation. There are currently 18 workstations.	R54 000
Profit due to sales	With a current throughput of 3575 chickens per hour, 22 days in a month and 8 hours in a working day, and profit value of R1 per chicken.	R456 400

Chapter 6

Evaluation and Validation of Alternatives

6.1. Throughput Evaluation of Alternatives

Table 19: Throughput Evaluation of Alternatives

Layout	Number of Workers	Whole Chickens	Portioned Chickens	Total Throughput
Current Layout	42	2727	384	3111
Conveyor Layout	39	4105	485	4590
Alternative Flow Layout	36	3175	400	3575

6.2. Economic Evaluation of Alternatives

The conveyor layout yields the highest monthly profits after the acquisition costs are paid with the first month's profits. The first month is the only month where the conveyor layout yields the lowest profits.

Table 20: Economic Evaluation of Alternatives

Layout	Profits (monthly)	Total Additional Profits
Current Layout	R345 936	None
Conveyor Layout	R601 604	R255 668 per month
Alternative Flow Layout	R 456 400	R110 464 per month

The break-even analysis for the profits of the layouts can be seen in Figure 15. The profits are accumulated on a monthly basis to indicate the total amount of profits made since the implementation, or potential implementation, of the alternative abattoir packaging department layouts. The conveyor layout has accumulated more profits than the current layout by the end of the third month with R179240. The conveyor layout has still accumulated less profit than the routes layout by the end of the fourth month with R6948, but by the end of the fifth month the conveyor layout has accumulated more profits with R138256.

From the second month onwards, the conveyor layout yields R255668 higher monthly profits than the current layout, and R145204 higher monthly profits than the alternative routes layout.

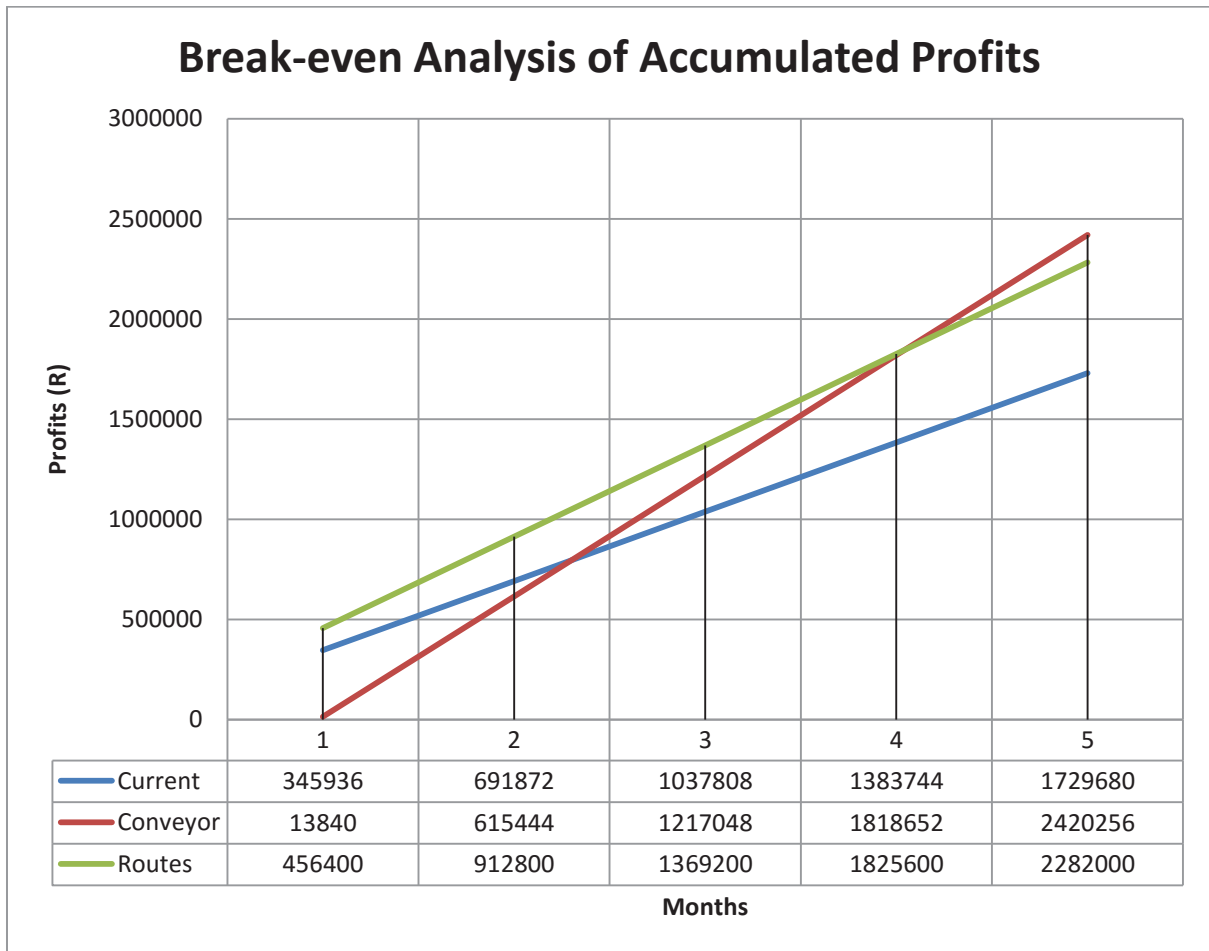


Figure 15: Break-even Analysis of the Layouts' Accumulated Profits

6.2. Analytic Hierarchy Process

6.2.1. Criteria Pairwise Comparison Matrix

The following criteria will be used to best evaluate the elements and characteristics of the different layouts to aid in the process of determining which layout will be the most advantageous for the abattoir of Kroon's Gourmet Chickens:

- ❖ Potential Delays: The layout's ability to prevent or minimise any potential delay within the department.
- ❖ Throughput: The throughput of products that the layout can process.
- ❖ Annual Operating Cost: The cost to operate and maintain the layout annually.
- ❖ Ease of Maintenance: The level of difficulty to maintain the layout and its equipment.

As the throughput of each layout will actually determine the amount of profit that is made for the company, the throughput of a layout will bear the most weight in the elements being considered in the layout comparison process. The annual operating cost is the factor that will determine how much of the throughput's gain will be spent on these costs. The potential delays in a layout are a factor that can greatly influence the amount of chickens processed in