A Conceptual Approach to Increase Competitiveness in a Typical South African Manufacturing SME

by

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Thesis presented in fulfilment of the requirements for the degree of Master of Engineering (Engineering Management) in the Faculty of Engineering at Stellenbosch University

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April 2019

Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the authorship owner thereof (unless to the extent explicitly otherwise stated), and that I have not previously, in its entirety or in part, submitted it for obtaining any qualification.

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Abstract

Global changes in the manufacturing landscape affect South African manufacturing small– and medium enterprises' (SME) competitiveness, as they must contend with global competition in international markets. To remain competitive is increasingly difficult in this ever-changing landscape and a company's success is to a large degree dependent on efficient operations. For a company to increase their efficiency, performance monitoring is essential. To capture performance measurement data there is an emphasis on real-time data collection, especially with the advent of the Fourth Industrial Revolution (referred to as Industry 4.0) and accompanying technologies.

Industry 4.0 will ultimately change the competitiveness of companies. The adoption of Industry 4.0, and subsequently real-time data collection, in South Africa (SA) is still relatively limited in comparison to the rest of the world, due to a variety of challenges related to: (i) the economic environment; (ii) the adoption of smart technology; (iii) the collaboration between industries, research institutions, and governments; (iv) education and awareness of Industry 4.0; and (v) the high percentage of unskilled workforces being employed.

The working environment in many South African manufacturing SMEs is still severely labour intensive, which can be attributed to South African policy makers and regulators who are trying to alleviate unemployment. However, a significant portion of the workers in these workforces are unskilled, which is a significant challenge to the SMEs. Moreover, these companies are also struggling to leverage technologies to their own benefit. It is argued that the transition towards Industry 4.0 in SA would take a considerable amount of time before the right foundation and polices would be in place.

Consequently, for these companies to remain competitive there is a need for an approach to guide them in improving efficiencies through active performance management. For this reason, this study presents a generic approach that a typical South African manufacturing SME, that either cannot or does not want to implement Industry 4.0 principles and technologies yet, can use in order to remain competitive in the everchanging landscape through increased performance management.

The generic approach was refined through a continuous process that was followed by using literature to analyse the use case, a Biltong Factory, for which a production management model was developed. The factory work is severely labour intensive, with a relatively low degree of the adoption of technology. Therefore, it can be argued that the Biltong Factory represents a typical South African SME.

The production management model that was developed for the Biltong factory used performance measurement data that were captured and analysed through various analyses. The model determined efficient process sequencing and worker allocation per process, while adapting to the types and number of orders received. The information obtained from the production management model assisted with informed decision making to achieve flexible and efficient operations, resulting in an increase of the Biltong factory's throughput, which had a significant impact on the factory's competitiveness.

Subsequently, the generic approach towards increasing and maintaining competitiveness was validated with the use of a questionnaire. Industry experts indicated that the approach can be used in future endeavours, which substantiates the argument that there is a need for such a tool for South African manufacturing SMEs.

Opsomming

Wêreldwye veranderings in die vervaardigingslandskap beïnvloed Suid-Afrikaanse vervaardigings klein– en medium ondernemings (KMO) se mededingendheid, aangesien hulle met internasionale markte moet meeding. Om mededingend te bly word toenemend moeilik in hierdie immer veranderende landskap en 'n onderneming se sukses is in 'n hoë mate afhanklik van doeltreffende bedrywighede. Vir 'n maatskappy om hul doeltreffendheid te verhoog, is prestasiemonitering noodsaaklik. Om prestasiemetingsdata vas te lê, is daar klem op intydse data-insameling, veral met die aankoms van die Vierde Industriële Revolusie (waarna verwys word as Industrie 4.0) en gepaardgaande tegnologie.

Industrie 4.0 sal uiteindelik die mededingendheid van ondernemings verander. Die aanneming van Industrie 4.0, dus ook intydse data-insameling, in Suid-Afrika (SA) is steeds relatief beperk in vergelyking met die res van die wêreld weens verskeie uitdagings wat verband hou met: (i) die ekonomiese omgewing; (ii) die aanvaarding van slim tegnologie; (iii) die samewerking tussen nywerhede, navorsingsinstellings en regerings; (iv) onderwys en bewustheid van Industrie 4.0; en (v) die hoë persentasie ongeskoolde arbeidsmagte wat in diens geneem word.

Die werksomgewing in baie Suid-Afrikaanse vervaardigings KMOs is steeds uiters arbeidsintensief, wat aktief deur die regering toegeskryf word aan Suid-Afrikaanse beleidmakers en reguleerders wat probeer om werkloosheid te verlig. 'n Beduidende deel van die werkers in hierdie werksmag is egter ongeskoold, wat 'n uitdaging vir die KMOs is. Daarbenewens sukkel hierdie maatskappye ook om tegnologie tot hul eie voordeel te benut. Daar word aangevoer dat die oorgang na Industrie 4.0 in SA 'n geruime tyd sal neem voordat die regte grondslag en beleid in plek sal wees.

Gevolglik, vir hierdie maatskappye mededingend te bly, is daar 'n behoefte aan 'n benadering om hulle te lei om doeltreffendheid te verbeter deur aktiewe prestasiebestuur. Om hierdie rede bied hierdie studie 'n generiese benadering wat tipiese Suid-Afrikaanse vervaardigings KMOs, wat nie tans Industrie 4.0 se beginsels en tegnologieë wil implementeer nie, kan gebruik om mededingend te bly in die immer veranderende landskap deur verhoogde prestasiebestuur.

Die verfyning van die generiese benadering was gebasseer op 'n deurlopende proses wat gevolg is deur literatuur te gebruik om die gebruiksgeval, 'n Biltong fabriek, te analiseer waarvoor 'n produksiestuurmodel ontwikkel is. Die fabriekswerk is arbeidsintensief, met 'n relatief lae mate van

die aanvaarding van tegnologie. Daarom kan aangevoer word dat die Biltong Fabriek 'n tipiese Suid-Afrikaanse vervaardigings KMOs verteenwoordig.

Die produksiebestuursmodel wat vir die Biltong fabriek ontwikkel is, het prestasiemetingsdata gebruik wat deur verskeie ontledings vasgevang en ontleed is. Die model het doeltreffende prosesvolgorde en werkerstoewysing per proses bepaal, wat volgens die bestelling tipe en volumes aangepas is. Die inligting wat verkry is van die produksiebestuursmodel het die fabriek gehelp met ingeligte besluitneming om buigsame en doeltreffende bedrywighede te bewerkstellig, wat 'n toename in die deurvoer van die Biltong fabriek tot gevolg gehad het. Dus, het dit ook 'n beduidende impak gehad op die mededingendheid van die fabriek.

Vervolgens is die generiese benadering tot die verhoging en handhawing van mededingendheid deur middel van 'n vraelys bevestig. Bedryfskenners het aangedui dat die benadering in toekomstige pogings aangewend kan word, wat die argument bevestig dat daar wel so 'n hulpmiddel vir Suid-Afrikaanse vervaardigingsondernemings KMOs nodig is.

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Glossary

Acronyms	**Abbreviations**
ABC	Activity Based Costing
AI	Artificial Intelligence
CAP	controlled atmosphere packaging
CI	Continuous improvement
CSIR	Council for Scientific and Industrial Research
DESC	Departmental Ethics Screening Committee
DMAIC	Define, Measure, Analyse, Improve, and Control
HACCP	Hazard Analysis Critical Control Points
IoT	Internet of Things
JIT	Just-in-Time
KPIs	key performance indicators
LM	Lean Manufacturing
MAP	modified atmosphere packaging
MLT	Manufacturing Lead Time
MT	Miscellaneous Time
MTM	Methods Time Measurement
PCM	Performance Centred Maintenance
PQ	Product-quantity
PTAs	Problem-Tree Analysis
RCA	Root cause analysis
ROI	return on investment
SA	South Africa
SCEA	Society of Cost Estimation Analysts
SMEs	Small to Medium Enterprises
SPC	Statistical Process Control
SS	Silverside
SS	Six Sigma
TOC	Theory of Constraints
TPS	Toyota Production System
TQM	Total Quality Management
US	United States
VBA	Visual Basic for Applications
VSM	Value Stream Mapping
5W2H	What? Why? Where? Who? When? and 2 how-questions
WIP	Work in Progress

Nomenclature

Symbol	Description	Units
TC	total annual cost	R/yr
C_f	fixed annual cost	R/yr
C_v	annual variable cost	R/pc
Q	annual quantity produced	pc/yr
$FOHR$	factory overhead rate	R/yr
$FOHC$	factory overhead costs	R/yr
DLC	annual direct labour costs	R/yr
$COHR$	corporate overhead rate	R/yr
$COHC$	annual corporate overhead costs	R/yr
DLC	annual direct labour costs	R/yr
UAC	uniform annual cost	R/yr
IC	initial cost of the machine	R
i	annual interest rate	
N	number of years	
C_o	hourly rate to operate the machine	R/hr
C_L	direct labour wage rate	R/hr
$FOHR_L$	factory overhead rate for labour	R/yr
C_M	machine hourly rate	R/hr
$FOHR_m$	factory overhead rate applicable to the machine	R/yr
C_{pc}	cost per piece	R/pc
C_m	cost of the starting material	R/pc
n_o	number of unit operations in the sequence	
C_{oi}	cost rate to perform unit operation i	R/min
T_{pi}	production time of operation i	min/pc
C_{ti}	cost of any tooling used in operation i	R/pc
C_i	inflation cost	
f_1	inflation rate in the first year	
f_2	inflation rate in the second year	
f_3	inflation rate in the third year	
C_p	cost in a base year	
T_c	cycle time	min/pc
T_o	time of the actual processing or assembly operation	min/pc
T_h	handling time	min/pc
T_t	average tool handling time	min/pc
T_p	average production time	min/pc
T_{su}	setup time	min/pc
R_p	average production rate	pc/hr
PC	production capacity	pc/period

H_{pc}	number of hours in the period being used to measure the production capacity
n	number of machines in the plant
R_{pi}	hourly production rate of machine *i*
$\boldsymbol{\delta}$	effect size
μ	mean
H_o	null hypothesis
H_1	alternative hypothesis
P	Power
η	Sample size
proc	process
p	process time
b	batches

Chapter 1

Introduction

The introductory chapter introduces the project, 'A Conceptual Approach to Increase Competitiveness in a Typical South African SME'. The research background and the origin of competitiveness, in a South African context is discussed. The background and origin provide an outline of the purpose of this research, as well as a brief background for the problem statement. Moreover, the introductory chapter presents the objectives that this project aims to achieve and the methodology that is used.

1.1. Research Background and Origin

The competition in the South African manufacturing industry has increased, as companies compete with global opposition in local and international markets due to increased globalisation. The amplified competition requires manufacturers to compete in several elements of its business, which includes quality, time and cost (Gibson, Greenhalgh and Kerr, 1995). To remain competitive, it is increasingly difficult in this ever-changing landscape, therefore a company's success is dictated by efficient operations (Squire *et al.*, 2006; Größler and Grübner, 2014; Lapré and Scudder, 2004; Hill and Hill, 2009). An essential aspect for competitive production and efficient operations, is the accurate determination of costs associated with the fabrication of a product (Conradie, 2015).

Moreover, manufacturers must understand the implications of the time, as well as the costs, that are associated with the production processes, by utilising cost-modelling approaches (Squire *et al.*, 2006; Größler and Grübner, 2014; Lapré and Scudder, 2004; Hill and Hill, 2009). For a company to achieve a competitive position, performance monitoring is essential. Thus, another essential aspect of effective manufacturing strategies or competitiveness is the regular tracking and monitoring of performance (Hill, 2000).

In most manufacturing companies the key measurement of performance is the cycle time (Thomas, 1990). This finding is supported by Maskell (1991), stating that for world-class manufacturing, a primary feature of performance measurement is the measurement of cycle time. By establishing performance measures, it enables a company to identify more efficient ways of doing things and also implementing them. Therefore, the cycle time can be used to measure the efficiency of a production process (Rother and Shook, 2003). To capture performance measurement data there is an emphasis on real-time data collection with the implementation of Industry 4.0.

Today, there is a large movement towards the Fourth Industrial Revolution (Industry 4.0) that will ultimately change the competitiveness of companies (Rüßmann *et al.*, 2015). Several definitions for Industry 4.0 exist, but essentially, it translates into a combination of digital and physical technologies, such as Artificial Intelligence (AI), Internet of Things (IoT), analytics and cognitive technologies (Breet, 2018). The increased integration between the digital and physical worlds allows for the establishment of a digital enterprise that is interconnected and also capable of informed decision-making (Breet, 2018).

The data obtained across machines and operations enables faster, more efficient and flexible processes. Therefore, there is a clear drive towards real-time data collection to produce higher-quality goods at reduced costs (Rüßmann *et al.*, 2015).

According to Pillay (2016), the adoption of Industry 4.0, and subsequently real time data collection, in South Africa (SA), is still relatively limited in comparison to the rest of the world. One of the reasons why adoption in SA lags behind the rest of the world, is the economic environment, which forces manufacturers in SA to rather save cost than spend on innovation. For greater adoption and development of Industry 4.0 applications in a company, more private or public incentives and investments are needed (Pillay, 2016).

Other reasons for the lagging adoption are the challenges of connectivity and accessibility. Therefore, the level of smart technology adoption remains at a foundation stage on the African continent for manufacturing companies (Pillay, 2016). Collaboration between industry, research institutions and government are also required in order to convey the gathered needed information about advanced manufacturing; to educate policy makers and industry leaders for a digital economy. Hence, huge potentials exist for collaboration between the different institutions to form skill development initiatives to upskill South Africans in crucial Industry 4.0 skills (Pillay, 2016; Malinga, 2018).

Companies also lack confidence that they have the correct talent in place to be successful in Industry 4.0 with the high employment of unskilled workforce (*The Fourth Industrial Revolution is here- are you ready?*, 2018). The weakened status of the South African education system has private sectors resorting to in-house training to bridge the skills gap required for Industry 4.0. With tight budgets in many companies this step is also undesirable (*South Africa, The Fourth Industrial Revolution & The Skills Gap*, 2018).

One of the key factors for South African manufacturing companies when deciding on upgrading or replacing systems and people, is the cost associated with these changes (Pillay, 2016). Dr Daniel

Visser, strategy manager in research and development for the Council for Scientific and Industrial Research (CSIR), made the following statement (Malinga, 2018),

> "While people may fear the introduction of automation and Artificial Intelligence, we are not looking at replacing jobs, but rather enhancing job creation and skills development. South Africa cannot do the fourth industrial revolution the same way that China or Germany does: they have a different context than South Africa. Within the South African context, the fourth industrial revolution is not about replacing jobs; it's about unlocking Africa's potential by augmenting jobs and making them safer and easier. Africa must not lose out in this evolution."

Although there are challenges associated with moving towards Industry 4.0, the Fourth Industrial Revolution movement generates innovation, creates unlimited possibilities and can ultimately improve competitiveness of companies (Breet, 2018).

The following list summarises a few reasons for the hindered adoption of Industry 4.0 in SA:

- Economic environment: More incentives and investments are needed.
- Challenges with connectivity and accessibility for the adoption of smart technology.
- Collaboration is required between industries, research institutions and government.
- Education regarding Industry 4.0 is required.
- Of unskilled workforce (less than matric), aged 15 – 64, 33.2% are employed, while 31.9% are unemployed (Maluleke, 2018).
- 39.3% of people, aged 15-34 years, are not employed, educated or trained (Maluleke, 2018).
- Unemployment rate is high, with 27.2% of the working age (15-64 years) being unemployed (Maluleke, 2018).

Small to Medium Enterprises (SMEs) in the South African context are defined as an enterprise that generates no more than R40 million per annum and have no more than 200 employees (Republic of South Africa, 1996). In addition to the above challenges SMEs also face challenges, regarding Industry 4.0 implementation, such as; labour law (OECD (Organization for Economic Cooperation and Development), 2015), crime (OECD (Organization for Economic Cooperation and Development), 2015), access to finance (Abedian *et al.*, 2007) and resources (Singer, Amorós and Arreola, 2015), access to market (Ladzani and Netswera, 2009), regulations and policies (Schwab, 2015), research and development (University Stellenbosch, 2016) and unskilled labour (University Stellenbosch, 2016).

This study presents a generic approach that a typical South African manufacturing SME, that either cannot or does not want to implement Industry 4.0 principles and technologies yet, can use in order to remain competitive in the everchanging landscape through increased performance management. A Biltong[1] Factory was studied as a use case.

The biltong market is extremely diverse and competitive, and the company with the best price and quality, often prevails as the customers' preferred choice. The Biltong Factory runs at maximum capacity and cannot commit to new big clients. Thus, they need to implement improvements in order to remain competitive. The factory work is labour intensive and relatively low technology driven, thus, representing a typical South African manufacturing SME.

1.2. Problem Statement and Research Methodology

This section describes the problem statement and aim of this research study. The identified objectives and methodology used to achieve these objectives of this study are also discussed.

1.2.1. Problem Statement

Global changes in the manufacturing landscape affect South African manufacturing SMEs' competitiveness, as they must contend with global competition in the local and international markets. Although, there is an international movement towards the adoption of Industry 4.0 principles and technologies, in South Africa the adoption lags behind the rest of the world due to a variety of challenges. Some of these challenges are only applicable to growing third world economies. Consequently, for these South African companies to remain competitive there is a need for an approach to guide them in maintaining their competitive edge.

1.2.2. Research Objectives

The aim of this study is to develop an approach to guide the process that a typical South African manufacturing SME can use to develop an improvement tool in order to increase their competitiveness. The approach is developed for South African manufacturing SMEs that either cannot or does not want to implement Industry 4.0 principles and technologies yet. This aim will be achieved with the following research objectives:

[1] Dehydrated meat. Popular South African snack.

Conduct a literature review to:

1. Determine whether there is a need for a guideline for South African manufacturing SMEs, to increase their competitiveness.
2. Identify and analyse strategies and tools for increasing the competitiveness of South African labour-intensive manufacturing SMEs.

3. Develop a production management model for a use case, a Biltong Factory, to increase their competitiveness through improved performance management. By achieving the following sub-objectives:
    a) Determine whether a Biltong Factory does represent a typical South African manufacturing SME.
    b) Determine whether the target area for improvement, required performance measurement data and production management model function, can be identified by the developed use case analysis methodology.

4. Develop a generic approach to guide the process of developing an improvement tool in order to increase competitiveness. By achieving the following sub-objective:
    a) Determine whether the literature investigated, together with the phases followed in order to develop a production management model for the use case, can be used to design the generic approach.

1.2.3. Research Outline

South African manufacturing SMEs need to adopt new methods and technologies to remain competitive in the ever-changing manufacturing landscape. However, this is often a costly venture and may not result in a significant return on investment (ROI) for the company. A generic approach is proposed to assist SME manufacturing companies in becoming more competitive by developing a tool to improve management of performance. Hence, the proposed generic approach will assist manufacturing SMEs in becoming more competitive without substantial change to their structure and day-to-day business.

Chapter 1 provides a description of the problem addressed in this research study. To achieve the research objectives of this study, the research is initiated by conducting a literature review in Chapter 2. Research on manufacturing industries is done to provide background and an understanding of manufacturing. Further, research is reviewed on competitive advantage concepts and tools.

Subsequently, background on biltong production is investigated in Chapter 3, as a Biltong Factory is used as a use case to develop a production management model to increase the factory's competitiveness. The reviewed literature is then used to develop a use case analysis methodology to guide the process of analysing the Biltong Factory. The biltong background information, together with the use case methodology, is then utilised to analyse the factory and to determine areas that need improvement in order to increase competitiveness.

The data required to develop the production management model is determined in Chapter 4 once the area that is in need of improvement is identified. Once the data required for the production management model is collected, the model function is then described. By establishing the function and data required, the production management model is then developed for the specific use case.

The next phase of the study, in Chapter 5, is to develop a generic approach for South African SMEs to guide the process of developing an improvement tool to increase their competitiveness. This will be based on the literature reviewed in earlier chapters, as well as the phases followed in the use case, to develop a production management model for them. To conclude the research, validation of the production management model, as well as the generic approach, is performed. Lastly, the research presents the conclusions and recommendations. Figure 1.1 illustrates the structure of the document to provide an outline of the study.

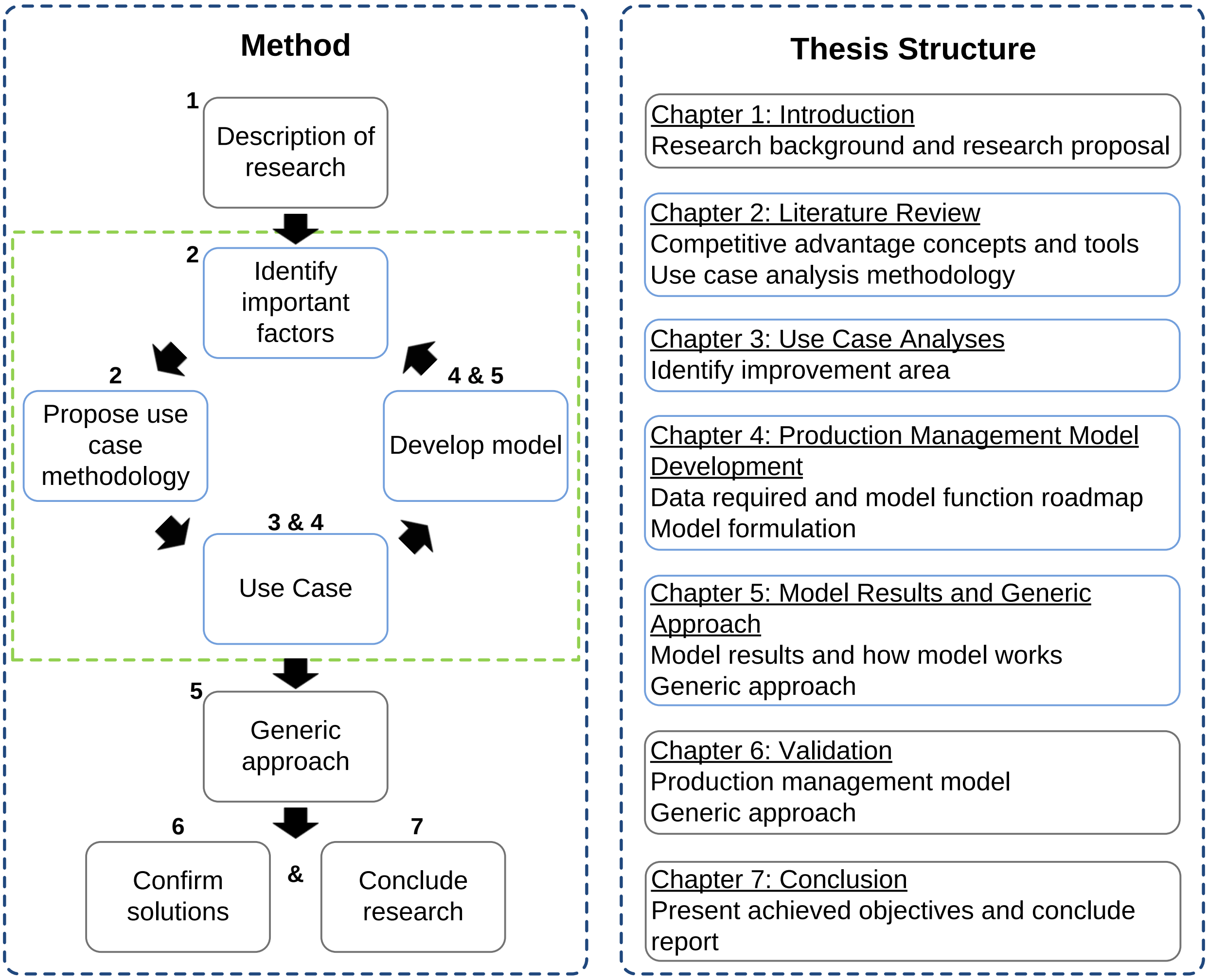


Figure 1.1: Method followed and the correlation to the structure of research document.

From the method in Figure 1.1, the 4-step process blocked in green is a continuous process followed in order to develop the generic approach to guide the process of developing an improvement tool in order to increase manufacturing SMEs' competitiveness.

The literature is used to propose a use case analysis methodology to guide the process to analyse the Biltong Factory and to develop the production management model. Based on the phases blocked in green in Figure 1.1, which were followed to develop the production management model for the factory, the generic approach development was continuously refined. After the production management model and the generic approach were finalised, the suggested solutions, namely the production management model and generic approach, were validated. The research was concluded by presenting the achieved objectives and findings.

1.2.3.1. Research Approach

There are two research approaches used in this study, namely quantitative and qualitative. The following techniques were used in this study to develop a production management model for a Biltong Factory.

- Observation: A period of time was spent at the Biltong Factory to gain an understanding of the biltong Value Chain. Moreover, observation was needed to identify possible improvement areas to increase the Biltong Factory's competitiveness.
- Use Case: A Biltong Factory is used in this research study. Data was collected at the factory and the production management model is specifically developed for the Biltong Factory.
- Case Study: By analysing the collected data from the factory the data was used to develop a production management model that was used to improve the efficiency of the factory.
- Questionnaire: To validate the generic approach a questionnaire was used to document industry opinions about the developed approach.
- Interview: To validate the developed production management model an interview was conducted with one of the owners of the Biltong Factory.

This study, thus, used qualitative analysis to determine an area for improvement within the use case, to focus on for developing the production management model. Quantitative analysis was used as the cycle times for the use case's production activities were determined through time-study experiments and this data was statistically analysed to develop the production management model. Therefore, this study used a combination of qualitative and quantitative analysis to conduct the research.

1.3. Ethical Implication

The researcher has been granted ethical clearance, with a 'low risk' assigned by the University of Stellenbosch Departmental Ethics Screening Committee (DESC). The risk assigned was classified as low, as this study didn't use personal information and the name of the Biltong manufacturing company is not disclosed in this research. The use case company is therefore referred to as 'the Biltong Factory' throughout this research document.

1.4. Chapter 1 Summary

Chapter 1 serves as a background for the rest of the research document. First, the research Background and Origin was explored, to provide a clear understanding of the problem and the aim that this study strives to solve. Secondly, the chapter presents the Problem Statement and Research Methodology and Research Approach followed in order to solve the research problem. Lastly, the Ethical Implication for this study is mentioned, as this research was conducted at a Biltong Factory.

Chapter 2
Literature Study

This chapter describes the literature that was used to achieve the research objectives of this study. Moreover, this chapter explains how the literature was used to develop a conceptual approach to follow to increase efficiency and in effect the competitiveness of a South African manufacturing SME. A literature review on manufacturing industries was done to provide background and an understanding on the manufacturing industry. Research was also conducted on competitive advantage concepts and tools, as the production management model that this study aims to develop will use these concepts and tools to increase the competitiveness of the use case, a Biltong Factory. Figure 2.1 provides the structure of the main topics that are reviewed for competitive advantage in Chapter 2.

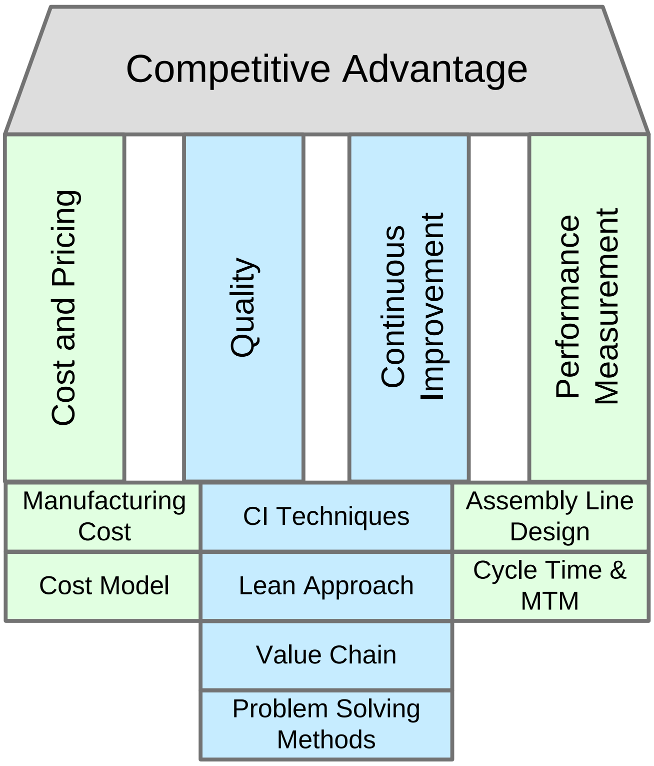


Figure 2.1: Structure of main topics investigated in competitive advantage literature review.

2.1. Manufacturing

Manufacturing is an important commercial activity, which is carried out by companies. The type of manufacturing a company performs is dependent on the kind of products it manufactures. Manufacturing can be generically defined as 'the application of physical and/or chemical processes to alter the properties, geometry, and/or appearance of a given starting material to make products or parts' (Groover, 2015). Manufacturing processes involve a combination of tools, machinery, power and manual labour. It is carried out in a sequence of unit operations, with each successive operation bringing the material closer to the final desired state.

From an economic viewpoint, manufacturing is concerned with transforming materials into items with greater value by means of processing and/or assembly operations. By changing a material's properties or shape, or combining it with other materials, manufacturing adds value to the material (Groover, 2015).

Manufacturing consists of different industries and can be classified into different categories. The industries consist of organizations and enterprises that supply and/or produce goods and/or services. Industries can be classified into three categories namely, primary, secondary and tertiary. Primary industries are industries that exploit and cultivate natural resources, such as mining and agriculture (Groover, 2015). Secondary industries are industries that convert the primary industries' outputs into products. Manufacturing is the principal activity in secondary industries, but this category also includes power utilities and construction. Finally, the service sectors of the economy are constituted by tertiary industries (Groover, 2015).

Production operations in the discrete product industries and process industries can be divided into batch and continuous production. Batch production occurs when materials are being processed in finite quantities or amounts (Groover, 2015). The finite quantity or amount of material is called a batch in both the discrete and process manufacturing industries. Batch production is discontinuous because interruption occurs in production of the different batches.

There are three main reasons for using batch production. It is used when differences between batches of work units necessitate changes in equipment, tooling and methods to accommodate the part differences (Groover, 2015). Another reason for using batch production is that the equipment capacity limits the quantity or amount of material being processed at one time. The final reason for using batch production is when the equipment's production rate is greater than the demand rate of products or parts, thus, the equipment produces in batches (Groover, 2015).

Continuous production occurs when, for a given product, the production equipment is exclusively used, and the product output is uninterrupted (Groover, 2015). In the process industries, this type of production means that the process has a continuous stream of material with no output flow interruptions. Continuous production for discrete manufacturing means no breaks for product changeover, as 100% dedication of the production equipment is being used for the part or product (Groover, 2015).

Different product varieties can also be manufactured at the same manufacturing plant. The differences in product variety can be categorised into two types namely, hard and soft product variety (Groover, 2015). When the products differ substantially it is a hard product variety. For an assembled product, this type of variety is characterized by a small proportion of common parts that exists among the different products. When there is only a small difference between products it is a soft product variety. Thus, amongst assembly products with a soft variety, a high proportion of common parts exist (Groover, 2015).

2.1.1. Production Layouts

For low production, the production facility quantity usually ranges between 1-100 units per year, called the *job shop* (Groover, 2015). The products are usually complex as a job shop makes customized and specialized products of low quantities. Thus, a job shop is designed for maximum flexibility to accommodate the wide range of product variations (hard product variety).

A *fixed-position layout* is a layout in which the product remains at the same location during the entire fabrication. Factories that have a *process-layout* usually manufacture the individual parts that these large products are comprised of. In this type of layout, the equipment is arranged according to type or function (Groover, 2015).

For medium production, the unit range is usually between 100-10 000 units annually. Depending on the variety, a distinction between two different types of facilities can be made namely *batch production* and *cellular manufacturing*. Batch production is typically used when the product variety is hard. Thus, after the batch of one product has been produced the facility is changed over to produce a batch of the next product. If the product variety is soft extensive changeovers between the different products may be required. The term cellular manufacturing is typically associated with this production type, as it is possible to configure the equipment in a way so that similar products can be manufactured using the same equipment (Groover, 2015).

For high production, also often referred to as *mass production*, the quantity usually ranges between 10 000 to millions of units per year. The situation can be categorized into *quantity production* and *flow-line production*. Quantity production involves mass production dedicating equipment to produce one-part type and a typical layout used is the process-layout. Flow-line production involves sequence arranged workstations and the assemblies or parts are moved through the sequence to complete the product (Groover, 2015).

To maximize efficiency the collection of stations is designed specifically for the product. This type of layout is called a *product layout*, as the workstations are arranged in one extended line or in a series of connected line segments. A small amount of total work on each unit of product is completed at each station (Groover, 2015). Figure 2.2 summarises the discussion of the types of production facilities.

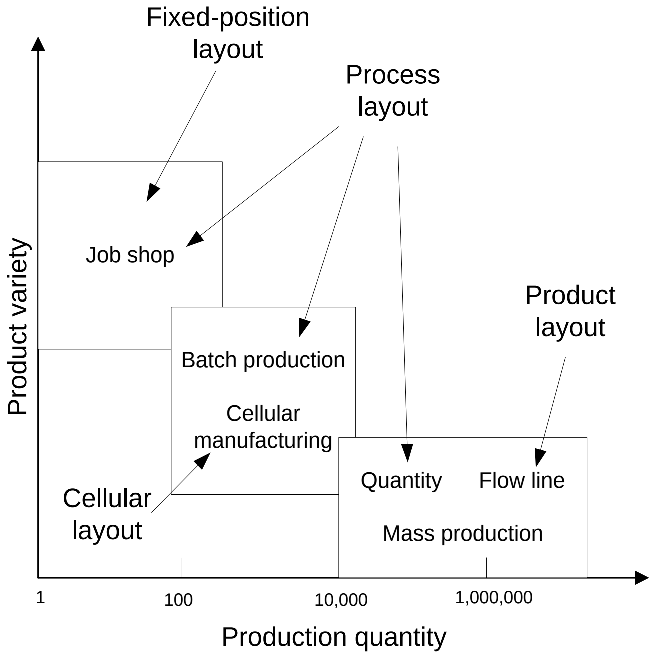


Figure 2.2: Types of layouts and facilities used for different levels of production and product variety adapted from (Groover, 2015).

This section provides an understanding of the manufacturing concept, product varieties and different production layouts in general. This research is applied to the use case in Chapter 3, to categorise the Biltong Factory's products and type of production layout they use.

2.2. Competitive Advantage

Competitive advantage is a set of unique features, of a company as well as its products, which are perceived by the customer target market as superior and significant to the competition. Thus, competitive advantage is the reason behind brand loyalty. It is well documented in literature that an important attribute of any product is cost and is highly relevant in the engineering design process (Hoult *et al.*, 1996; Wierda, 1990; Curran, Raghunathan and Price, 2004). Sheldon Huang and Perks (1991) stated that the three key elements of competitiveness are: product quality, customer affordability and market timeliness. According to Mayer and Nusswald (2001), the three main goals for an enterprise's success are high quality, low lead times, and low costs.

The state of competition in the market effects prices as the environment becomes more competitive with more suppliers in the market (Gowthorpe, 2005). In order for companies to maintain their competitiveness at the highest possible level, companies are forced to produce high-quality and low-cost products (Shehab and Abdalla, 2001).

The quality and time aspects of a product have a contesting nature to cost, thus, when improvements in quality are above what is required it is considered an unnecessary waste of resources (Squire *et al.*, 2006; Größler and Grübner, 2014; Lapré and Scudder, 2004; Hill and Hill, 2009). On the other hand, improvements on time allows for a higher production rate, thus, also improving efficiency and cost effectiveness. Manufacturers must therefore understand the implications of the time as well as the costs that are associated with the production processes by utilising cost modelling approaches (Squire *et al.*, 2006; Größler and Grübner, 2014; Lapré and Scudder, 2004; Hill and Hill, 2009).

The ability to respond quickly to competitive moves is also of key significance to stay competitive in some market sectors. When this is done effectively the impact of the competition's promotions, product tests or new products, can be reduced (West, 1989). The focus shift to alternative means to remain competitive has created an increased interest in Value Chains. The Value Chains are being used to formulate strategies and model the extended enterprise to remain competitive (Feller, Shunk and Callarman, 2006).

A powerful tool for creating competitive advantage is a competitive scope as companies often differ in their activities or competitive scope. A competitive scope has four key dimensions namely, vertical scope, segment scope, geographic scope and industry scope. A broad scope can allow companies to exploit the interrelationships between Value Chains that serve different related industries, geographical areas, or industry segments. A company can exploit potential benefits to perform more activities internally rather than using outside suppliers by employing a broad vertical scope (Porter and Millar, 1985).

A narrow scope on the other hand may enable a company to tailor the Value Chain for a target segment to achieve differentiation or lower cost. A narrow scope allows customizing the Value Chain to serve product buyers, variety or geographical regions in the best possible way. This provides a competitive advantage for a narrow scope, as a broad scope will not serve target segments that have unusual needs well (Porter and Millar, 1985).

These three main competitive advantage goals, namely: cost, quality and low lead times, were the foundations for this research. Based on these competitive advantage goals, the main focus areas or cornerstones for achieving competitive advantage are identified as: cost and pricing, quality, continuous improvement, and performance measurement (depicted in Figure 2.3). The cornerstones identified for competitive advantage are further discussed in the latter sections.

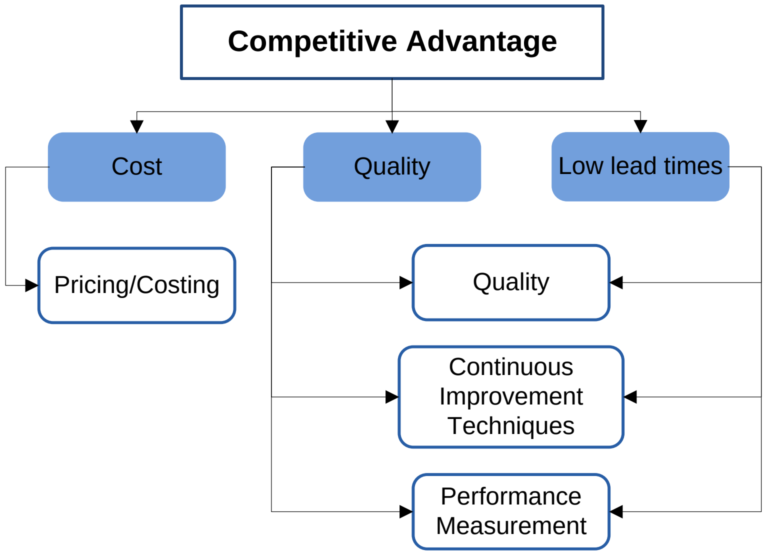


Figure 2.3: Competitive advantage cornerstones.

2.2.1. Cost and Pricing

Pricing is of great importance as organisations are run with a view of profit and competitive advantage. Businesses suffer or even fail when prices are set too low to cover expenses in the medium or long term. Critical elements in the determination of prices are the supply and demand (Gowthorpe, 2005).

In a pure market environment, prices are pushed up when there is a scarcity of supply of a commodity, and lower available quantities also command higher prices. On the other hand, lower prices result from plentiful supply. Therefore, a theoretical interaction exists between quantity and price. Figure 2.4 illustrates this interaction (Gowthorpe, 2005).

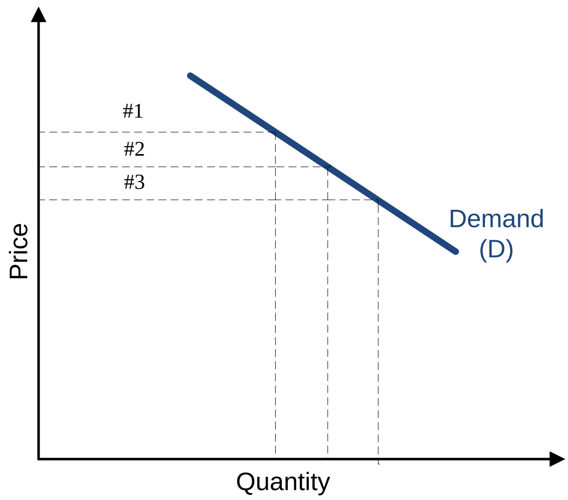


Figure 2.4: Interaction between quantity and price on demand curve adapted from (Gowthorpe, 2005).

The three sets of dotted lines in Figure 2.4 describe the following: Set #1 illustrates the supply of lower quantity goods with the relative scarcity reflected by a higher price. Sets #2 and #3 illustrate the positions of progressively higher supply resulting in relatively lower prices.

The more price/quantity relationships plotted, the more price/quantity relationships emerge - this is referred to as a demand curve. When there are more suppliers in the market, a state known as 'perfect competition' is approached (set #2), as a more competitive environment exists. No individual supplier can set significantly higher prices, because there are many suppliers. Thus, prices and suppliers can reach an equilibrium state where dramatic movements are unlikely to take place (Gowthorpe, 2005).

The cost position of a company reflects the collective cost of carrying out all the value activities relative to rivals. Potential sources of cost advantage are determined by each activity's cost drivers. The company's Value Chain activities reflect the company's ability to differentiate itself. These activities include more than the activities needed to produce a physical product or service, all of which contribute towards fulfilment of the customer needs (Porter and Millar, 1985).

When the value that the company creates exceeds the performing costs of value activities a business is profitable, thereby resulting in a profit margin. The value system activities can cooperate to reduce cost and improve their efficiency to achieve a higher total margin. To assign margins for each stage in a Value Chain, a price is calculated for each activity. Thus, the amount of value each activity adds to the product is evaluated. An understanding of the margins in the whole Value Chain provides a comprehensive understanding of the demand and supply forces, which is the essence of corporate strategy that focusses on operational excellence (Feller, Shunk and Callarman, 2006; Beyers, 2017).

A business' position in a market can determine whether it has control over prices or not. In a market with many suppliers of goods and/or services, in other words an intensely competitive market, there may be limited scope available for individual suppliers to separate from the pack. Therefore, markets are often dominated by a few large suppliers that are trailed by several smaller providers. Small providers are unlikely to be able to affect prices (Gowthorpe, 2005).

This type of provider is called the *price taker* and must take the prices that are determined by the more powerful or influential players in the market. A *price setter* on the other hand, does not have to accept prices that are set by other people (Gowthorpe, 2005). Price takers therefore, have little scope for making decisions regarding prices compared to price setters. As a result, producers and suppliers should pay more attention to demand and market conditions (Gowthorpe, 2005).

Market-based pricing is sometimes based upon experience and perception of market demand. Thus, when market information is accessible, or can be obtained, businesses should use it. *Cost-based pricing* is based on the cost required to provide a product or service, thus, the price is fixed (Gowthorpe, 2005). In the longer term, cost-based pricing generally cannot be executed without any reference to the market. It is likely that a problem exists when a cost-based price results to be higher than the price of similar products or even identical products in the market (Gowthorpe, 2005).

A business is likely to fail when these higher costs are the result of inherent defects or inefficiencies in the manufacturing process. The high cost can also be a result of the businesses changing their source of supply. This increased cost due to the mentioned results can lead to the business being priced out of a particular market (Gowthorpe, 2005).

Many businesses provide discounts on selling prices to ensure early payments for products supplied on credit, or to reward customer loyalty. The supplier's profit margin is reduced by a small margin through providing such discounts but is usually balanced out by a commensurate benefit, where certain customers ensure a greater amount of business, leading to higher guaranteed sales (Gowthorpe, 2005). Businesses even sell goods or services at a price less than what it costs to produce them. This can lead to the rapid downfall of the business when it is done too often over a wide product range, but it can also make sense in certain instances such as (Gowthorpe, 2005):

- The goods or services are treated as a loss leader.
- There is a large quantity of inventory with a short shelf-life to clear.

A *loss leader* product or service is used to attract consumers' attention to a particular supplier or a range of goods. A loss leader can therefore help a business to break into a particular market segment (Gowthorpe, 2005).

2.2.2. Quality

Stewart *et al.* (1995) stated that the environment of the new economic age is one in which the competition is global for customers. The key to surviving in this economic age is quality. Quality can be defined as providing customers with what they need or want at a price they are willing and able to pay (Steward, Wyskida and Johannes, 1995). Cost is therefore an important parameter when the customer defines value, thus it must be an important parameter when decisions regarding what to offer to the customer is made (Steward, Wyskida and Johannes, 1995).

Quality considerations broadly include product design, performance, marketing, delivery, after sales service and other non-price factors. In some industries, quality or non-price factors are on average as important as, or more important than price (Buxton, Chapman and Temple, 1998). In most markets, there are essentially many more dimensions regarding quality on which competition can differentiate a product and/or service than price dimensions. Thus, in some industries it is more likely that the quality factor will be the decisive factor that influences the customer's choice (Buxton, Chapman and Temple, 1998).

According to Buxton *et al.* (1998), the term quality has two rather different interpretations. In marketing and economics, the products' quality is defined to include design, performance, distinction, style, desirable features, branding, level of service and reliability. Alternatively, a narrower definition is used in operations management that refers to the process as well as the product's quality. Therefore, when referring to total quality or quality control, the term means freedom of defects.

The two different uses of the term quality can cause confusion, as it relates to the way in which prices, as well as costs, are thought of to relate to quality. For the marketer or economist, as quality increases, prices and costs are also expected to increase. However, in operations management this relationship is misleading (Buxton, Chapman and Temple, 1998). For a given state of a production process, costs will decrease as the process is further optimised and refined.

Thus, costs should decrease as the incidents or defects decrease and quality increases. In many competitive settings, there are theoretical grounds to anticipate quality to be of larger importance than price. If the dimensions for quality are large, then it can be said that the aspects of quality are of greater significance than price, both as a source of competitive advantage and in a purchasing decision (Buxton, Chapman and Temple, 1998).

2.2.3. Continuous Improvement

Continuous improvement (CI) involves a company-wide process of small progression steps to enable focused incremental innovation (Bessant *et al.*, 1994). This production philosophy is focused on creating a culture that uses a conscious, unceasing improvement programme to attain perfection (Dan Reid and Sanders, 2007).

The objective of CI is to create an atmosphere that governs continuous learning that embraces change and innovation. Therefore, the CI philosophy sustains a competitive advantage among an organisation's competitors (Ramadan, Al-maimani and Noche, 2017). To describe this ongoing process of improvement efforts, the Japanese use the word 'kaizen' and in the United States they use the term 'zero defects' (Heizer and Render, 2006). Techniques used to implement CI are discussed in Section 2.5.

2.2.4. Performance Measurement

Customer satisfaction plays an equally important role as in profit generation, specifically in many competitive and successful manufacturing businesses. The importance of customer satisfaction can be seen through the way operations managers strive, daily, to deliver the best products, within the shortest possible time, and at a reasonable price. Thus, an enterprise's success is measured in terms of three economic global goals namely, high quality, low lead times as well as low costs (Mayer and Nusswald, 2001). Manufacturing Lead Time (MLT) is the duration of time between when an order is received from a customer, until the order is invoiced or delivered (Chikez, 2016).

Successful manufacturing companies that strive to meet these economic global goals use a variety of quantitative metrics to identify and track problems with performance, as well as make good decisions (Groover, 2015). Therefore, the tracking and monitoring of performance regularly, is also seen as the cornerstone of effective manufacturing strategies (Hill, 2000). In order for a company to achieve a competitive position, performance monitoring is essential (Gibson, Greenhalgh and Kerr, 1995).

In every company the key measurement of performance is the cycle time (Thomas, 1990). This finding is supported by Maskell (1991), stating that for world class manufacturing a primary feature of performance measurement is the measurement of cycle time (Maskell, 1991). By establishing performance measures, it enables a company to identify more efficient ways of doing things and implementing them. Therefore, the cycle time can be used as an indicator to measure the efficiency of a production process (Rother and Shook, 2003). Section 2.9.3 discusses cycle time in more detail.

Section 2.2 provides the key factors that need to be considered by a company to be competitive. The three global economic goals are quality, time and cost.

2.3. Types of Manufacturing Costs

This section provides an understanding of the different types of costs to a company. Therefore, the discussion is part of the cost and pricing cornerstone of competitive advantage.

2.3.1. Direct versus Indirect Costs

Direct costs are directly linked to a product, while indirect costs are not directly linked. Thus, by using a pre-defined base, indirect cost must be allocated through a process known as cost allocation (Steward, Wyskida and Johannes, 1995). Another way of viewing costs is to classify them as period or product costs. Period costs are incurred costs in the period of account, such as the salaries of sales and marketing personnel. Product costs are related to the production of goods or services and it includes direct and indirect production costs (Gowthorpe, 2005).

Cost allocation is described by Steward *et al*. (1995), as the interpretation and categorisation of costs to come to a reasonable distribution of those costs. Volume-based allocation is the traditional approach to allocate overheads.

If the wrong allocation base is defined, the volume-based methods for allocating overhead costs could lead to incorrect conclusions, as these methods imply that indirect and direct costs are proportional (Curran *et al.*, 2004). This is not always the case when considering the trend in industry to use automated equipment. Production line automation implies higher indirect cost for the more expensive equipment, and lower direct cost as it is less labour intensive. Thus, it is becoming more important to generate estimates that are accurate for indirect cost (Essmann, 2012).

2.3.2. Fixed versus Variable Costs

Classifying costs according to their variability can be very useful when making decisions (Gowthorpe, 2005). Manufacturing costs can be categorized into two major categories, namely fixed costs and variable costs. Fixed costs remain constant within a certain range for any production output and can be expressed as annual amounts (Groover, 2015). Thus, it does not vary with the business activity level (Gowthorpe, 2005). Examples of fixed costs are production equipment, factory building, insurance and property taxes.

Variable cost on the other hand, varies in proportion or in line with the production output. Therefore, as the output increases, the variable costs increase as well. Examples of variable costs are raw material, direct labour and electricity. By adding the fixed and variable costs together the total cost can be calculated by using Equation 2.1 (Groover, 2015):

$$\boldsymbol{TC = C_f + C_v Q} \qquad \textbf{2.1}$$

Where TC is the total annual cost, R/yr; C_f is the fixed annual cost, R/yr; C_v is the annual variable cost, R/pc; and Q is the annual quantity produced, pc/yr.

Fixed costs are typically higher for automated methods relative to manual methods. On the other hand, the variable cost of automation is again lower relative to manual methods, as depicted in Figure 2.5. Thus, automation has a cost advantage for higher production quantities and the manual method has an advantage for the low quantity range (Groover, 2015).

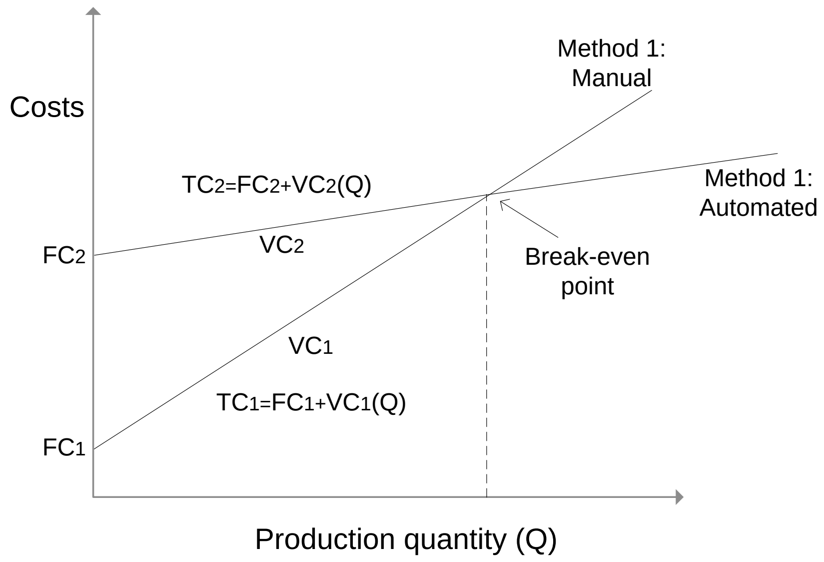


Figure 2.5: Fixed and variable cost for manual and automated methods adapted from (Groover, 2015).

Costs can also be classified as semi-variable. This type of classification has both fixed and variable elements as it varies, to some extent, to the proportion of business activities. For example, telephone bills have a line rental charge, which is fixed. In addition to this fixed line rental there is also a variable element that varies depending on the number of phone calls made (Gowthorpe, 2005).

2.3.3. Direct Labour, Material, and Factory Overhead

An alternative classification to fixed and variable cost is to separate costs into direct labour, material and factory overhead costs. In the manufacturing environment these are the three basic components of cost (Gowthorpe, 2005). A component classification is often a more convenient method used to analyse production costs. The material and labour costs are direct inputs in the manufacturing process and the factory overheads are indirect inputs (Gowthorpe, 2005).

The cost associated with direct labour, is the sum of the benefits and wages paid for workers, who perform the assembly and processing tasks as well as operate the production equipment (Groover, 2015). Operator rates paid to the personnel operating a plant can be obtained from a company labour relation supervisor, or a union contract (Durr, 2016).

The raw materials' costs used to make the final product are known as the material costs. The definition of the raw material depends on the type of production operations and on the company (Groover, 2015). The raw material expense is normally the largest manufacturing expense and thus the most obvious direct expense (Durr, 2016).

The direct labour and material cost of a company can be considered as variable costs. Also included under direct costs is maintenance cost, as it consists of materials and labour components (Durr, 2016). An example of variable labour costs are commissions, thus paying a worker according to their output. Labour cost can also be a fixed cost with fixed labour contracts, as these costs are incurred, whether there is work or not (Thompson, 2018).

Overhead costs can be divided into two categories, factory and corporate overhead (Groover, 2015). Overhead expenses include all the expenses associated with running the manufacturing firm, but are not themselves identifiable with produced individual items (Gowthorpe, 2005). Costs, other than direct labour and materials, which are also associated with operating a factory, are called factory overhead expenses. Table 2.1 lists examples of typical factory overhead expenses (Groover, 2015).

Table 2.1: Typical Factory Overhead Expenses adapted from (Groover, 2015).

Line foreman	Lighting	**Material handling**
Maintenance crew	Insurance	**Equipment depreciation**
Tool crib attendance	Taxes	**Factory depreciation**
Plant supervisor	**Power for machinery**	**Shipping and receiving**
Security personnel	Heat and air conditioning	Fringe benefits
Custodial services	**Payroll services**	**Clerical support**

Corporate overhead expenses are the costs that are not related to the company's activities associated with manufacturing. One of the reasons for dividing expenses into factory and corporate overhead costs are that many companies operate multiple factories (Groover, 2015). Thus, different factories can have significantly different factory overhead expenses. Table 2.2 lists examples of typical corporate overhead expenses (Groover, 2015).

Table 2.2: Typical Corporate Overhead Expenses adapted from (Groover, 2015).

Legal counsel	Fringe benefits	Lighting
Sales and marketing	Research and development	Security personnel
Corporate expenses	Engineering	Office space
Finance department	Insurance	Taxes
Accounting department	Other support personnel	Heat and air conditioning

The examples of typical factory overheads in Table 2.1, that are not in bold are also listed in Table 2.2 indicating that similar overhead costs can be related to both factory and corporate overhead cost. Thus, to distinguish between these two types of overhead costs is essential to structure costs orderly.

The allocation of cost can be classified and compiled into four categories: direct labour, material, factory overhead and corporate overhead.

With the objective to define an overhead rate that can be used for the following years, the factory overhead is calculated using the following equation:

$$\boldsymbol{FOHR} = \frac{\boldsymbol{FOHC}}{\boldsymbol{DLC}} \quad \textbf{2.2}$$

Where $FOHR$ is the factory overhead rate, R/yr; $FOHC$ is the annual factory overhead costs, R/yr; and DLC is the annual direct labour costs, R/yr.

The corporate overhead is calculated through the following equation:

$$\boldsymbol{COHR} = \frac{\boldsymbol{COHC}}{\boldsymbol{DLC}} \quad \textbf{2.3}$$

Where $COHR$ is the corporate overhead rate, R/yr; $COHC$ is the annual corporate overhead costs, R/yr; and DLC is the annual direct labour costs, R/yr. Both of these rates are often expressed as percentages (Groover, 2015). Figure 2.6 provides typical percentages for corporate and manufacturing expenses.

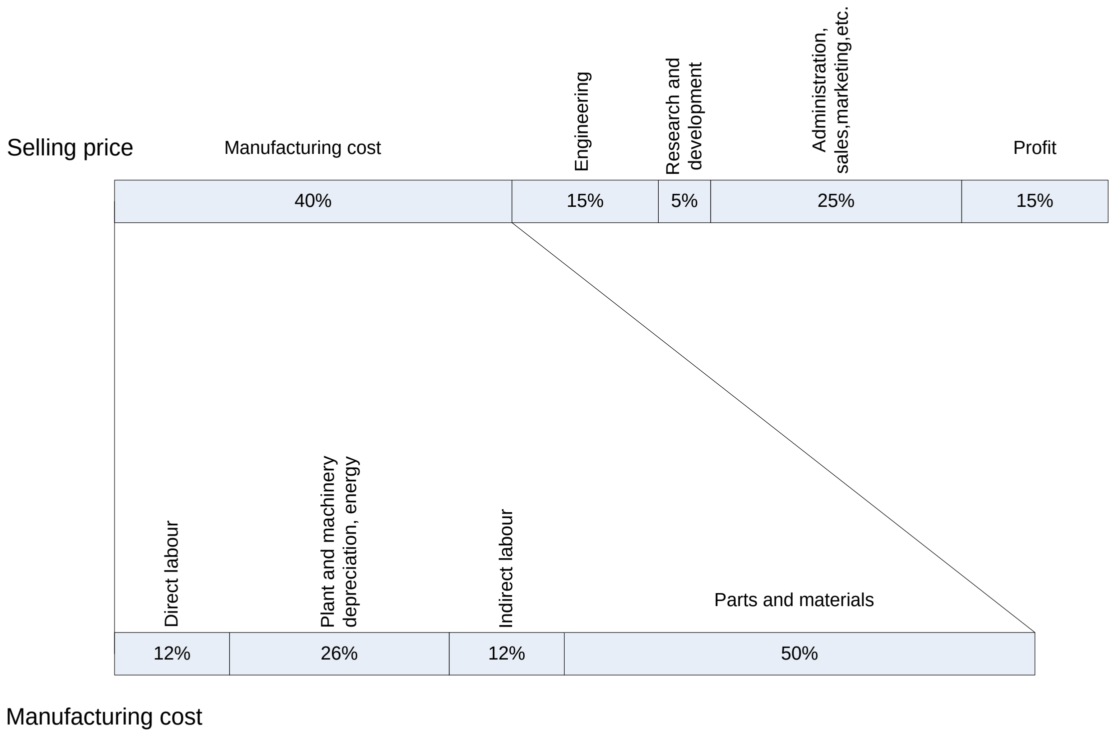


Figure 2.6: Breakdown of costs for a manufacture product adapted from (Groover, 2015).

The following observations can be made about the data depicted in the above figure. First, the total manufacturing cost is only about 40% of the products' selling price. Total manufacturing cost and corporate overhead expenses are almost equal. The largest percentage, 50%, of the total manufacturing cost is made up by the material cost.

Lastly, a relatively small proportion of the total manufacturing cost is made up by direct labour; only about 12% of the manufacturing cost (Groover, 2015). For the South African context and especially manufacturing SMEs this cost will be more as they make use of manual labour, therefore, they are more labour intensive.

2.3.4. Cost of Equipment Usage and Manufactured Part

The concern with the overhead rates as discussed above is based on labour cost alone. The overhead structure does not accurately depict the manufacturing costs; as the differences in rates of the different production machines are not recognised. To deal with this difficulty, the cost associated with a worker running a machine can be divided into two components namely, direct labour cost and machine cost (Groover, 2015).

The initial costs of a machine allocated over the life of the asset at the suitable rate of return used in the firm, are the machine annual cost. The equivalent uniform annual cost are calculated by Equation 2.4 (Groover, 2015).

$$\boldsymbol{UAC = IC(A/P, i, N)} \tag{2.4}$$

Where UAC is the equivalent uniform annual cost, R/yr; IC is the initial cost of the machine, R; and $(A/P, i, N)$ is the capital recovery factor that converts the initial cost at year 0 into an equivalent uniform series of annual year-end values, where i is the annual interest rate and N is the number of years of the service life of the equipment. $(A/P, i, N)$ can be computed as follows:

$$\boldsymbol{(A/P, i, N) = \frac{i(1+1)^N}{i(1+1)^N - 1}} \tag{2.5}$$

The unit cost of a manufactured product or part is the sum of the material cost, production cost and tooling cost. Overhead cost and profit mark-up need to be added to the unit cost to arrive at the product's selling price.

The sum of the labour and machine costs is the total cost rate for the machine. The hourly rate of one machine and one worker to operate a machine can be calculated as follows (Groover, 2015):

$$\boldsymbol{C_o = C_L(1 + FOHR_L) + C_m(1 + FOHR_m)} \tag{2.6}$$

Where C_o is the hourly rate to operate the machine, R/hr; C_L is the direct labour wage rate, R/hr; $FOHR_L$ is the factory overhead rate for labour; C_m is the machine hourly rate, R/hr; and $FOHR_m$ is the factory overhead rate applicable to the machine. The $FOHR$ values can be calculated by using Equation 2.2.

The sum of the raw material costs and the costs of all unit operations are the total unit cost of the part and are calculated through the following equation:

$$\boldsymbol{C_{pc} = C_m + \sum_{i=1}^{n_o}(C_{oi}T_{pi} + C_{ti})} \qquad \textbf{2.7}$$

Where C_{pc} is the cost per piece, R/pc; and C_m is the cost of the starting material, R/pc; and the summation includes the cost of n_o number of unit operations in the sequence; C_{oi} is the cost rate to perform unit operation i, R/min; T_{pi} is the production time of operation i, min/pc, and is calculated by Equations 2.9 and 2.10; and C_{ti} is the cost of any tooling used in operation i, R/pc (Groover, 2015).

For a project that will be installed at a future time, it is necessary for the cost estimation to account for inflation from the estimation time, to the planned installation time. Thus, it deals with adjusting future values. Equation 2.8 provides an example for a project planned three years in advance.

$$\boldsymbol{C_i = (1 + f_1)(1 + f_2)(1 + f_3)C_p} \qquad \textbf{2.8}$$

Where C_i is the inflation cost; f_1 is the inflation rate in the first year; f_2 is the inflation rate in the second year; f_3 is the inflation rate in the third year; and C_p is the cost in a base year (Durr, 2016).

To calculate the cycle time by considering the processing, handling and tool handling time the following equation can be used.

$$\boldsymbol{T_c = T_o + T_h + T_t} \qquad \textbf{2.9}$$

Where T_c is the cycle time, min/pc; T_o is the time of the actual processing or assembly operation, min/pc; T_h is the handling time, min/pc; and T_t is the average tool handling time, min/pc, if such an activity is applicable (Groover, 2015).

By taking the sum of the set up and cycle time the average production time can be calculated by using the following equation:

$$\boldsymbol{T_p = T_{su} + T_c} \qquad \textbf{2.10}$$

Where T_p is the average production time, min/pc; T_{su} is the setup time to prepare the machine to produce the part, min/pc; and T_c is the cycle time calculated by Equation 2.9.

To calculate the production rate for the unit operation the following equation can be used (Groover, 2015).

$$\boldsymbol{R_p = \frac{60}{T_p}} \quad \textbf{2.11}$$

Where R_p is the average production rate, pc/hr; T_p is the production time from Equation 2.10; and the constant 60 converts minutes to hours.

To calculate the production capacity in cases where different machines produce different parts at different production rates the equation below can be used (Groover, 2015).

$$\boldsymbol{PC = H_{pc} \sum_{i=1}^{n} R_{pi}} \quad \textbf{2.12}$$

Where PC is the production capacity, pc/period; H_{pc} are the number of hours in the period being used to measure the production capacity; *n* is the number of machines in the plant; and R_{pi} is the hourly production rate of machine *i*.

2.3.5. Cost Classification

To keep track of costs to control and plan business activities as well as value finished goods in stock and Work in Progress (WIP), it is necessary to allocate costs to products. Finished goods in stock and WIP are carried forward, at production cost, to the next accounting period (including direct labour, materials and production overhead cost). This cost accumulation is known as *absorption costing* (Gowthorpe, 2005).

Job costing refers to the cost information that relates to work chargeable to one client. By accumulating the cost in this way, the price at which the services or goods are to be invoiced can be established (Gowthorpe, 2005).

Product costing terminology is used when the costing information for each type of manufactured product is gathered. This is performed by manufacturing industries that produce goods of a generic type to replenish general stocks of finished goods. It is appropriate in manufacturing industries to produce goods in production runs of convenient size or in batches. When the costs are allocated to each run or batch it is known as *batch costing* (Gowthorpe, 2005).

Marginal costing is used to describe an approach that excludes fixed costs. It provides a much sounder basis for making decisions. *Contribution* refers to the remaining amount after the variable costs have been deducted from the sales amount; it is calculated using the following equation (Gowthorpe, 2005).

$$\boldsymbol{Sales\ price\ per\ unit - Variable\ cost\ per\ unit = Contribution\ per\ unit} \qquad \mathbf{2.13}$$

If the contribution amount is positive it contributes to meet the fixed costs of the business. When a sufficient contribution is made in order to cover all the business' fixed costs, the remaining amount contributes to the net profits (Gowthorpe, 2005).

Section 2.3 provides an understanding of different manufacturing costs, which can be analysed to understand the different manufacturing costs of the use case a Biltong Factory. This section also provides formulas to calculate the manufacturing costs, as well as the production rate and capacity. The next section will investigate cost modelling or detailed cost estimates that are based on specific cost detail.

2.4. Cost Model

Cost modelling, according to the Society of Cost Estimation Analysts (SCEA), can be defined as a compilation of cost estimating logic, which aggregates cost estimating details into a total cost estimate (Essmann, 2012). Cost modelling can also be described as the ordered arrangement of data, equations and assumptions that permit the translation of physical characteristics or resources into costs. Curran *et al.* (2004), describe cost modelling as a set of logic, equations, input and program formats that specify the problem. This set of logic and equations characterise the cost to manufacture a product or component.

Cost models, also known as cost estimating models, enable organisations to make intelligent decisions regarding design and production, which ultimately influences the final cost of the product. The process of forecasting or predicting the cost of a work output or activity is known as cost estimating (Curran, Raghunathan and Price, 2004).

For a business activity or an organisation to be powerful and credible, cost estimation should be considered an integral and dynamic part of the financial and technical functions. It is essential for efficiency and an optimum competitive posture, to have an active and inseparable relationship between cost accounting, cost management functions and cost estimation (Steward *et al.*, 1995).

Cost estimation is solicitous with the costs that are related to a set of activities that have not yet been executed. Cost estimation can be broadly classified as variant-based models, parametric techniques, intuitive methods and generative cost estimating models (Shehab and Abdalla, 2001). However, by using the generative approach the most accurate cost estimates are prepared. A critical factor to successfully implement a cost estimation system is accurate cost data. One of the earliest attempts for estimating manufacturing cost is operation-based cost models (Shehab and Abdalla, 2001).

Cost estimating can be divided into two main estimates, namely a detailed estimate and a first sight estimate. Detailed estimates are associated with precision costing and are based on recorded specific cost details, such as the time per operation, number of operations, material cost, labour cost and overhead costs etc (Curran, Raghunathan and Price, 2004).

On the other hand, first-sight estimates are made early in the design process and are useful for rough order magnitude estimate. This type of estimate provides useful information at an early stage of product definition, but is not suitable for product detail decisions (Curran, Raghunathan and Price, 2004). A more detailed classification for estimating methods has been provided by Boehm (1984) and includes the following:

- Expert judgement: Advice of knowledgeable staff is solicited.
- Parametric: Using cost drivers that model and represent certain characteristics of the implementation environment and target system.
- Price to win: A significantly low figure in order to win the contract.
- Parkinson: The premise that work expands, to fill the time available and to drive the estimate, the available resource level is used.
- Analogy: A project that is similar and already completed is identified to use the recorded cost as a basis.
- Bottom-up: Component tasks are sized and identified to aggregate individual estimates to produce an overall estimate.
- Top down: Overall estimates of effort can be broken down into the required efforts for individual components of the project as a whole.

Boehm (1984), refers to these seven entities as ‘software cost estimation techniques. The ‘Parkinson’ method can be viewed as a way of setting the project scope rather than a prediction method. Similarly, ‘Price to win’ can be seen as a pricing tactic rather than a prediction method (Boehm, 1984; Curran, Raghunathan and Price, 2004)

The necessity for cost models stems from three widely recognised product effectiveness measures', namely quality, product cost and time to market. The effectiveness of a product is determined by whether the customer's demands are met and whether the product contributes to the commercial success. Product cost is an afterthought in many companies, with the primary focus on time to market or quality. This approach is not sustainable for companies in highly competitive markets (Essmann, 2012).

Traditional ideas regarding the nature of cost is that they are only determined in the production stage. In the understanding of cost there has been a paradigm shift over the last few decades, especially in terms of when costs are committed, as opposed to when costs are incurred (Essmann, 2012).

Figure 2.7 illustrates this concept of the nature of cost. It presents an overview in terms of when cost is committed versus when cost is incurred over the product life. The figure, however, serves to illustrate the general case rather than to reflect all situations precisely (Essmann, 2012).

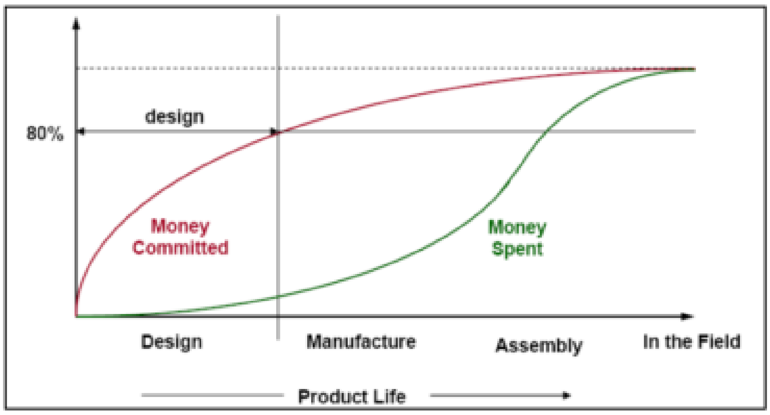


Figure 2.7: The nature of cost (Essmann, 2012).

It can be seen from Figure 2.7 that already 80% of the total product cost is committed in the design stage. At this time, only a small fraction is accrued of the product cost. Thus, at the early stages of product development, the final product cost can be greatly influenced.

Engineers are responsible for the decisions made during the product design stage. Therefore, there is an increased realisation in the manufacturing industry that the engineers are held responsible for the final product cost (Essmann, 2012). There is also a need to integrate the decision-making process with cost. A means of doing this is provided by cost models, by modelling cost incurred downstream in terms of the upstream design variables (Essmann, 2012).

According to Shehab and Abdalla (2001), it is more effective to reduce the cost of a product at the design stage than at the manufacturing stage. Therefore, the product can be modified to achieve reasonable cost as well as proper performance; if the cost of the product manufacturing can be established during the early design stage. Previous studies have indicated that during the conceptual design stage it determines over 70% of the product's production cost (Shehab and Abdalla, 2001).

Therefore, it is necessary to devote a greater effort towards design to cost-to-optimise product cost. Cost can be used as an evaluation criterion in design, as it can be employed either in a design-for-cost or design-to-cost context. Design-for-cost is to reduce the life cycle cost by consciously engineering the process technology (Shehab and Abdalla, 2001). It can also be thought of as an engineering forward-feeding process, which uses process information during design and can be directly aligned with concurrent engineering (Essmann, 2012).

On the other hand, design-to-cost provides for a given cost target, a design that satisfies the functional requirements (Shehab and Abdalla, 2001). Design-to-cost makes use of target costing to reach a cost objective, thus it is more management driven. Whether the design-for-cost or design-to-cost approach is taken for cost integration it is still part of concurrent engineering methodology (Essmann, 2012). Concurrent engineering is described by Groover (2008) as an approach used during product development in which manufacturing, design and other functions are integrated to reduce the time to market (Groover, 2015). In the context of cost modelling, a benefit of concurrent engineering is that it allows higher potential for achieving target costs and greater cost control, as the cost drivers can be quantified and identified early in the product development cycle (Essmann, 2012).

2.4.1. Challenges Associated with Cost Modelling

Although cost modelling has been the topic of much research, it is still not readily applied in manufacturing industries (Conradie, 2015). Manufacturing industries still prefer not to implement cost modelling due to the following: Firstly, the companies do not deem the effort necessary to uphold results accuracy, reasonable compared to the savings that can potentially be achieved. Secondly, the input processes that are associated with the methods are considered to be too tedious and complex (Conradie, 2015). According to Conradie (2015), there is a lack of knowledge regarding the cost modelling process.

Curran *et al.* (2004), identified four barriers limiting the implementation of cost-modelling techniques:

1) Cost model validation;
2) Complexity of cost;
3) Non-objectivity of cost estimates and
4) Cost drivers outside design scope.

Manufacturing operations include a great number of elements that are either differentiated in complex modes, interrelated or both. Advanced cost engineering is usually associated with modelling techniques that are used predominantly in academia and research for the purpose of lifecycle analysis, economic viability studies, and project cost estimation support (Conradie, 2015). Also associated with modern production systems and designs, are inherent complexities and dynamics that make it difficult to control, estimate and monitor costs (Conradie, 2015).

The Cost modelling section indicates that cost estimation and the prediction of cost for work output, is essential for efficiency and an optimum competitive posture. Therefore, it forms part of the cost and pricing cornerstone for competitive advantage. This section also states that detailed estimates are associated with precision costing and are based on recorded specific cost details.

Section 2.4 discusses the types of manufacturing costs needed for detailed estimates associated with precision costing. These types of costs were already discussed in more detail in the previous section, Section 2.3. The following section will investigate continuous improvement techniques and identify a technique that will be investigated further.

2.5. Continuous Improvement Techniques

This section forms part of the quality and continuous improvement cornerstones for competitive advantage as discussed previously in Section 2.2. The 8 techniques under review in this section are the Toyota Production System, Six Sigma, Statistical Process Control, Theory of Constraints, Total Quality Management, Performance Centred Maintenance, Cost Saving and Business Restructuring, and Lean Manufacturing. These techniques are briefly reviewed to identify a technique that will undergo further investigation. Further research is then conducted on the identified continuous improvement technique.

2.5.1. Toyota Production System

The Toyota Production System (TPS) was developed by Taiichi Ohno, a Japanese industrial engineer and businessman, to improve the Toyota Motor Corporation production (Ohno, 1988). TPS, a continuous improvement methodology, focuses on breeding an improvement culture by treating the employees as knowledgeable workers and by empowering them with the autonomy to correct any problems at their workstations. Thus, ultimately ensuring a high standard of work. The basis of the TPS is to eliminate waste (Ohno, 1988). The two main TPS pillars, illustrated in the Figure 2.8, are Just-in-Time (JIT) or continuous flow and process autonomation or *Jidoka*.

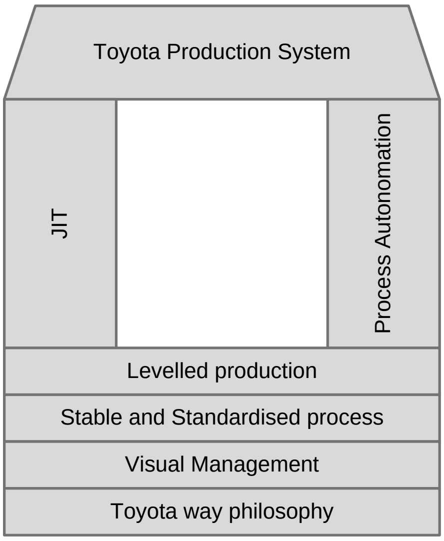


Figure 2.8: Toyota Production System adapted from (Ohno, 1988).

JIT refers to making what is needed, when it is needed, and only the amount that is needed. The second pillar *Jidoka* or process autonomation (intelligent automation) is used for the JIT system to function by ensuring that all the parts are meeting the predetermined quality standards (Tapping, Luyster and Shuker, 2002). The 'Toyota way philosophy' illustrated above is a set of behaviour norms and principles that should be cultivated by an organisation to successfully implement TPS (Ohno, 1988). The TPS is further discussed in more detail under Key Concepts of Lean in Section 2.6.1, as it is the part of the foundation of Lean.

2.5.2. Six Sigma

Six Sigma (SS) is a comprehensive system that can be used to achieve sustainable business success by eliminating quality defects. The SS methodology is facilitated by a cycle to reinvent and improve the business process. The method consists of Define, Measure, Analyse, Improve, and Control (DMAIC). The objective of the SS methodology is a defect free production process (Vermeulen, Pretorius and Kruger, 2013; Mabizela, Oosthuizen and Pretorius, 2015).

2.5.3. Statistical Process Control

Statistical Process Control (SPC) is a methodology that is utilised for managing, monitoring, maintaining and improving processes by using statistical methods (Mabizela, Oosthuizen and Pretorius, 2015). By implementing SPC it effectively reduces the scrap rate, product recalls, warranty costs, reworks. It also increases market share, profit margins, and productivity (Mabizela, Oosthuizen and Pretorius, 2015).

The process utilises control charts, which are like those used in Six-Sigma, to adjust a process when going out of statistical control before the process diverges out of the statistical limit (Mabizela, Oosthuizen and Pretorius, 2015). Some data to be measured include quality costs, process output quality and process performance. The interpretation of the statistical results provide information on achieving high quality products, by adjusting the processes in an appropriate way where it is deemed necessary (Mabizela, Oosthuizen and Pretorius, 2015).

2.5.4. Theory of Constraints

Theory of Constraints (TOC) is a methodology that promotes systematic improvements and the management of important limiting factors or system constraints in the production line, which currently stand in the way of achieving higher performance (Pretorius, 2014). The five-step systematic procedure, used to identify and eliminate constraints (bottlenecks), is illustrated in Figure 2.9:

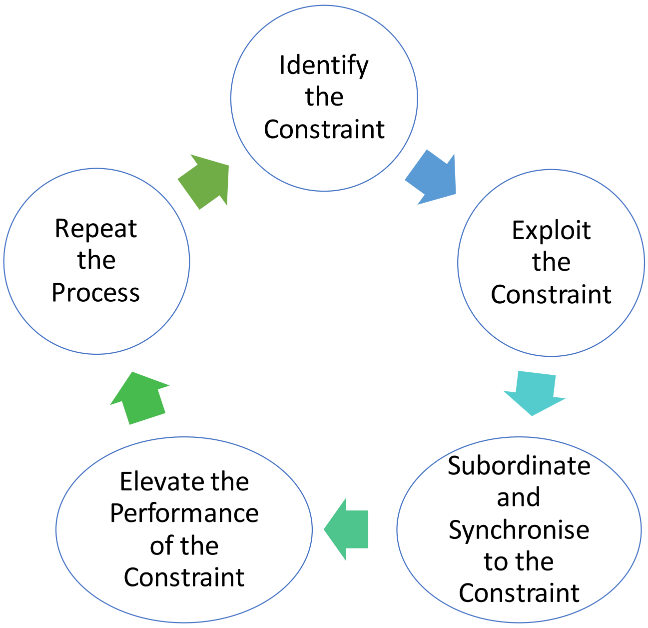


Figure 2.9: Theory of Constraints five step procedure adapted from (Vorne, 2017).

2.5.5. Total Quality Management

Total Quality Management (TQM) describes a management philosophy that focuses on long-term success through customer satisfaction and employee involvement. It uses data, strategy, and effective communication as drivers for continuous improvement to integrate the quality discipline and process performance into the activities and culture of the organisation (Erickson, 1992).

The 8 primary principles of TQM are (*Total Quality Management: What is TQM? | ASQ*, 2018):

1. Customer-focused: The customer determines the level of quality.
2. Total employee involvement: The employees work towards common goals.
3. Process-centred: Involves process thinking, a series of steps to transform inputs to outputs. These steps are defined, and performance measures are monitored to detect unexpected variation.
4. Integrated system: Connects business improvement elements to improve continuously and exceed customer and employee expectations.
5. Strategic and systematic approach: Strategic planning and management involves the formulation of a strategic plan by integrating quality as the core component.
6. Continual improvement: To drive an organisation to be both creative and analytical to find ways to become more effective and competitive.
7. Fact-based decision making: To determine how well an organization is performing TQM requires continual collection and analysing of data in order to improve decision making accuracy.
8. Communication: Effective communication are required to maintain morale and to motivate employees.

2.5.6. Performance Centred Maintenance

The focus of Performance Centred Maintenance (PCM) is to ensure high quality by maintaining assets and ensuring the performance of physical assets continues at the required level. Strategies include corrective maintenance, breakdown maintenance, condition based maintenance, time based maintenance, and reliability centred maintenance (Groenewald, Kleingeld and Vosloo, 2015). The PCM strategy for continuous improvement is based on the plan-do-check-act cycle as illustrated in Figure 2.10:

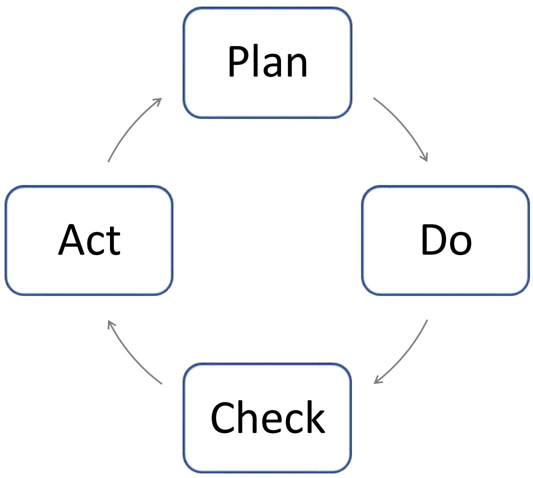


Figure 2.10: Performance Centred Maintenance cycle adapted from (Groenewald, Kleingeld and Vosloo, 2015).

The first phase ‘Plan’ establishes the intended objectives or outcome of the process. This phase also includes the development of plans to achieve the desired objective or outcome. The second phase ‘Do’ involves the implementation of the plans that were developed in the previous phase. The ‘check’ phase assesses the implemented plan’s results that were achieved and compares it to the intended outcome. The final phase ‘Act’ is based on whether the achieved results satisfy the objectives that were established in the ‘Plan’ phase (Groenewald, Kleingeld and Vosloo, 2015).

If the objective is not yet achieved, the cycle is repeated, from the ‘Do’ phase, until the set of objectives are satisfied. After the objectives have been satisfied, the initiation of a new cycle, with new desired objectives, is initiated and the cycle starts again from the ‘Plan’ phase (Groenewald, Kleingeld and Vosloo, 2015).

2.5.7. Cost Savings and Business Restructuring

Cost savings and business restructuring focusses on improving business performance by re-organising the enterprise through rationalising strategy to increase operating efficiency. This strategy aims to cut cost. As a result, the method improves profits and bottom line savings (Darnton, 2017). The procedure entails policy adjustments, company size reduction, and product alterations. Thus, when implementing this method in a mechanistic way all the organization’s departments are often affected. By implementing the rationalising procedure, long-term organisational performance improvement are not guaranteed when other operation dynamics are not taken into consideration (Claassen, 2016).

2.5.8. Lean Manufacturing

The main objective of any company that offers a product or service is to eventually become a Lean organisation (Mabizela, Oosthuizen and Pretorius, 2015). Lean organisations focus on maximising product value by eliminating waste in their systems or processes (Ramadan, Al-maimani and Noche, 2017; Womack and Jones, 2003). Eliminating process waste includes the elimination of any activity that adds cycle time, costs and consumes resources without creating value. Therefore, by eliminating process waste, organisations reduce costs that can be translated to higher productivity and also higher market share (Mabizela, Oosthuizen and Pretorius, 2015).

From the above discussion of the different continuous improvement techniques there are clear links or similarities with Lean Manufacturing (LM). The links or similarities as mentioned above are the following:

- Tapping *et al.* (2002) states that the terms Lean Manufacturing and Toyota Production System are interchangeable. The two main pillars, JIT and process autonomation (*Jidoka*), focus mainly on continuous flow, which is also the main goal of LM.
- Six-Sigma and Statistical Process Control are also covered in LM, as the Lean approach strives to eliminate the eight deadliest waste. Similar to LM, Six-Sigma and Statistical Process Control are also used to eliminate defects; thus, they can be used as tools to achieve a Lean production system.
- To implement the 5-step procedure of Theory of Constraints, Lean tools can be used as illustrated in Figure 2.11:

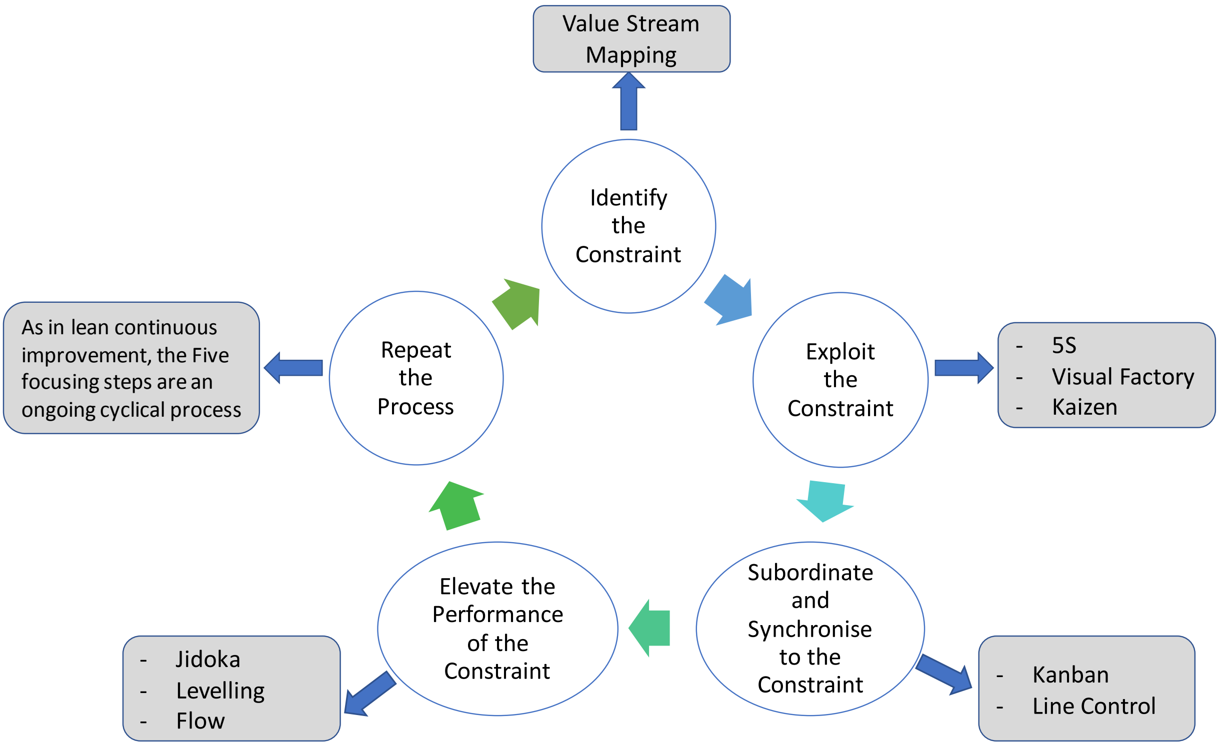


Figure 2.11: Theory of Constraints five step procedure utilizing Lean Manufacturing tools adapted from (Vorne, 2017).

- The following table represents the similarities and differences between Lean and TQM.

Table 2.3: Similarities and differences between Lean and TQM (Anvari, Ismail and Hojjati, 2011).

Subject	Lean	TQM
Approach:	Elimination of waste and understand customer value.	Quality; Focus on customer.
Process view:	Continuous improvement; Improve flow in processes.	Continuous improvement; Improve and uniform processes.
Fundamental concept:	Improving the value created for the customers. The customers pull value through a streamlined value stream.	Orientation towards customers and suppliers, employee driven, and data based.
Methodologies and Tools:	Customer value, value stream, analysis, flow, pull, perfection. Analytical tools.	Plan, do, check and act. Analytical and statistical tools.
Effects:	Reduces lead time and inventory. Increases productivity and in effect increases customer satisfaction.	Through improved performance achieve increased customer loyalty though customer satisfaction.

- PCM helps to ensure that accurate maintenance is undertaken. Thus, it can be linked to Lean, because Lean also strives to eliminate waiting and inappropriate processing waste. The PCM procedure plan-do-check-act can also be used in Lean to implement new production plans.

- Cost savings and business restructuring focusses on improving business performance by re-organising the enterprise to cut cost through increasing operational efficiency. Improving business performance through continuously improving an enterprise is also part of the fundamental concept of the Lean approach.

From the earlier discussion LM has similarities with all the CI reviewed techniques. The Lean approach was, therefore, further investigated as an approach for increasing efficiency and in effect increase the competitiveness of an enterprise. From Section 2.6 onwards these sections provide a literature review on the Lean manufacturing approach and tools that can be used to implement Lean and identify problem areas.

2.6. Lean Approach

The Lean approach originated in the Toyota Motor Corporation's practices. The theory was codified and made popular through publications such as 'The Machine That Changed the World and Lean Thinking' (McManus and Millard, 2002). The focus of these writings was mainly on manufacturing aspects, rather than on the design and engineering processes of business. The writings still maintain that identical principles can be applied to both non-shop floor and shop floor activities (McManus and Millard, 2002).

Lean Production has emerged as a global concept used to integrate different tools, to ultimately focus on manufacturing products that meets customer's needs and to eliminate waste (Braglia, Carmignani and Zammori, 2011). The following are some of the tangible benefits of becoming Lean (Tapping, Luyster and Shuker, 2002):

- Sharpens perception;
- Promotes cooperation;
- Shortens feedback loops;
- Speeds corrective action and
- Improves process reliability.

Womack and Jones (2003) identified Lean thinking's first principle as defining the value from the customer's perspective (Feller, Shunk and Callarman, 2006). In accomplishing this principle, the production system needs to strive for perfection and must be characterised by a strained levelled flow, which is driven by customer demand (Braglia, Carmignani and Zammori, 2011).

The main tenets of Lean can be categorised as (McManus and Millard, 2002):

- *Value*: Providing the customer with the right product, at the right time, for the right price.
- *Value stream*: The set of actions or activities that bring the product from raw material to finished goods, order to delivery, or concept to realization.
- *Pull*: Rather than pushing or forcing a product upon the marketplace, focus on only satisfying customers needs.
- *Flow*: Seamless movement through value-creating activities or steps.
- *Perfection*: Relentlessly and continuously improving the value, flow, value stream, and pull in business operations.

Lean Production development requires an analysis of the 'value stream' once 'value' has been defined. The value stream includes all the activities that are required to bring a product from raw material to the end customer. Wasteful steps then have to be eliminated to introduce flow in the remaining value-added processes (Braglia, Carmignani and Zammori, 2011).

To create an improved future state of a process, the current state of a process needs to be mapped to apply Lean technique, namely Value Stream Mapping, as discussed in Section 2.8.2. The non-value-adding tasks, or the tasks that are completely unnecessary in themselves, need to be identified to develop this future state. The non-value-added tasks can be referred to as Type I waste, which are often tasks such as reviews and set-ups (McManus and Millard, 2002).

The unnecessary tasks can be referred to as Type II waste, which is often "non-tasks" such as components waiting in inventory. The future improved state map drives an implementation plan and is then used for further future states to continuously improve the process. The improvements methods, standard terminology and symbols allow Value Stream Mapping (VSM) to be used as a tool to communicate techniques and results both internally and within the larger Lean community (McManus and Millard, 2002).

2.6.1. Key Concepts of Lean

The key concepts of Lean section are based on a Book titled 'Value Stream Management' by Tapping, Luyster and Shuker. The concepts of Lean that need to be understood to assess the current state and to develop the future state effectively, are the following (Tapping, Luyster and Shuker, 2002):

1) The cost reduction principle: The primary means of maximising profit by reducing costs through eliminating waste from value stream.
2) The eight deadly wastes: Discussed in Section 2.6.2.

3) Two pillars of Toyota Production System: Just-in-Time (JIT) production and *Jidoka* (also known as process autonomation or intelligent automation).
4) The 5S system: A key prerequisite for Lean as it is designed for the organization and standardization of any workplace.
5) Visual Workplace: The essence of the visual factory is "just-in-time information".
6) Three stages of Lean application: Demand, flow and levelling.

The first key concept of Lean is cost reduction. Management is constantly under pressure from customers to maintain the highest quality as well as reduce costs and lead times. In today's competitive market, customers often set the price they are willing to pay. Thus, the traditional method of setting the sale's price, by calculating cost and adding a profit margin, does not apply in today's competitive market.

In these conditions the only way to remain profitable is by eliminating waste, thereby reducing cost. The new method is to first determine the price the customer is willing to pay and then subtract the cost to determine what the profit will be. Figure 2.12 illustrates the different methods.

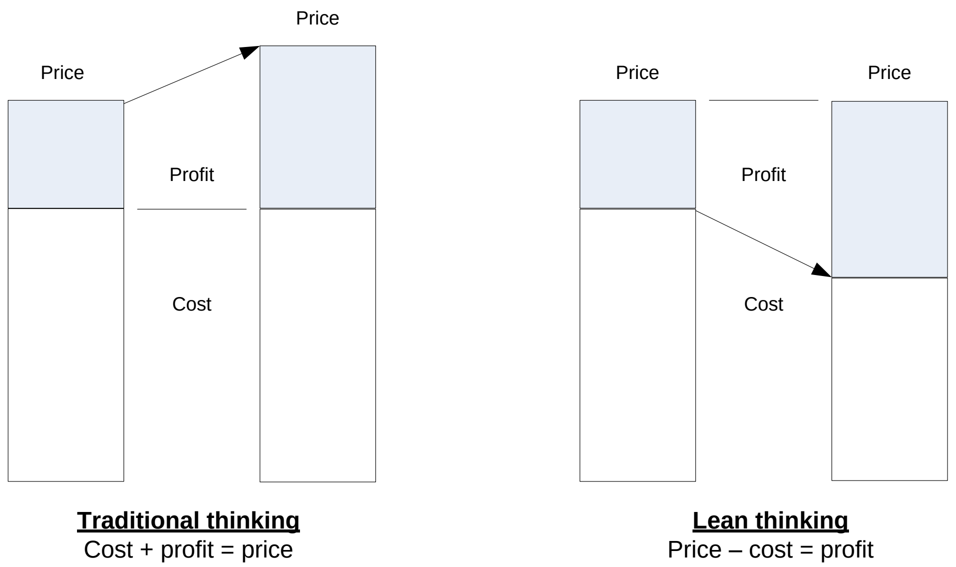


Figure 2.12: Cost plus versus price minus adapted from (Tapping, Luyster and Shuker, 2002).

The Toyota Production System is one of the most highly-developed Lean systems. The two pillars that support the Toyota Production System are JIT production and *Jidoka* (process autonomation). These pillars' foundations rest on the people as well as the critical role they play to eliminate business process waste and manufacturing waste.

JIT is the ideal state for continuous flow that is characterised by the capability to replenish a part that has been pulled by the customer. The goal of JIT, or continuous flow, is to provide customers with high-quality products with high delivery and order requirements. Therefore, only those units ordered, just when they are needed and in the exact amount needed.

The term *Jidoka* means to mistake-proof defect detection by the practical use of automation or process autonomation and to free up workers to be able to perform multiple tasks in work cells (Tapping, Luyster and Shuker, 2002). The ultimate goal of *Jidoka* is zero defects, implying that defective products must never be passed to the downstream and to eliminate the possible risk that an undetected defect product will reach the customer.

The 5S system is a prerequisite to implement other improvement methods and consists of the following 5 activities (Tapping, Luyster and Shuker, 2002):

- *Sort*: Removing unnecessary items by sorting through the contents of an area.
- *Set in Order*: Arranging necessary items for efficient and easy access and keeping it that way.
- *Shine*: Cleaning and keeping everything clean to ensure that your equipment and area is maintained in a way that it should be.
- *Standardise*: Creating guidelines to keep the area orderly, organized, and clean, and making these standards obvious and visual.
- *Sustain*: Communicating and educating to ensure that the 5S standards are followed by everyone.

The 5S standards are not only for housekeeping. It will have a positive effect on the performance that will be reflected by; reduced total lead time, elimination of accidents and shorter changeover times.

A visual workplace uses pictures that are available exactly where you need it, when you need it, with just the right information. Thus, the essence of a visual factory or workplace is “just-in-time information”. The final key concept is the three stages of Lean application, which are defined as follows (Tapping, Luyster and Shuker, 2002):

1) Customer demand stage: Understanding different aspects of customer demand for your products, including lead time, quality characteristics and price.
2) Flow stage: Implementing continuous flow manufacturing throughout so that external and internal customers will receive the right product at the right time in the right quantity.
3) Levelling stage: Distributing the volume and variety of work evenly, to reduce WIP and inventory.

The common goals, by conducting *kaizen* events focused in each of these stages are to:

- *Stabilize* your processes, equipment capabilities, reviewing customer demand, labour balance and material flow.
- *Standardise* processes and the work.
- *Simplify* through *kaizen* after the processes have been standardized and stabilized.

The first stage of Lean application is demand. A concept used to determine and meet demand is takt time, also known as the pace of customer demand. The term "takt" is a German word for a musical rhythm or beat, thus, it keeps the beat for customer demand. Therefore, takt time indicates the rate at which a company must produce their product to satisfy the demand.

Therefore, companies need to synchronise the production pace with the pace of sales. Takt time may be adjusted as the order volume increases or decreases to synchronise production and demand. The following formula can be used to calculate the takt time for a value stream or particular product family.

$$\boldsymbol{Takt\ time} = \frac{\boldsymbol{Available\ production\ time\ or\ Time}}{\boldsymbol{Total\ daily\ quantity\ required\ or\ Volume}} \qquad \textbf{2.14}$$

After determining customer demand a commitment needs to be made to meet it. If the demand cannot be met confidently with the current production systems, tools such as buffer and safety inventory can be used. Buffer inventory is used if the production process is incapable of meeting a faster (lower) takt time, when the customer demand unexpectedly increases (Tapping, Luyster and Shuker, 2002).

Safety inventory is used to protect the company from internal problems such as quality problems, equipment reliability problems, labour power issues and power outage that could possibly prevent the company from meeting their demand. Buffers and safety inventory are only temporary measures to meet demand while implementing and planning improvements to meet the company's ideal state. As the ideal state is reached, when demand becomes more stable and the company improves the reliability of processes and operations, the inventory should be reviewed periodically to minimize or eliminate these excess or waste inventories.

The second stage of the Lean application is flow. A tool that can be used to reach the flow stage is line balancing. Line balancing is a process in which the work elements within a value stream are evenly distributed to meet the takt time. It optimises the use of personnel as it balances workloads so that no one does too much or too little.

To implement line balancing the current state needs to be analysed. A tool used to perform this analysis is an operator balance chart, which is a visual display of each workstation's work elements, time requirements and operators. By displaying each operation's times in relation to total cycle time and takt time, the tool visually shows improvement opportunities.

There are three steps for creating an operator balance sheet, they are (Tapping, Luyster and Shuker, 2002):

1) Determine the current cycle times as well as the total cycle time of all the work element assignments.
2) Create an operator balance bar chart that gives a visual representation of the current state condition. The bar chart that follows will clearly show if the line is out of balance and where the imbalance exists. Thus, whether the operators' takt time meets or is below the dotted takt line as illustrated below.

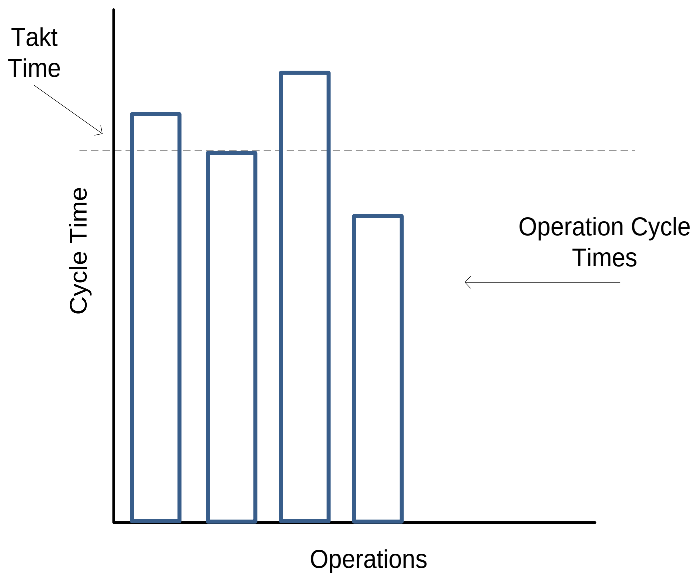


Figure 2.13: Operator balance chart adapted from (Tapping, Luyster and Shuker, 2002).

3) The final step is to determine the number of operators that are required by dividing the total product cycle time by the takt time depicted in Equation 2.15.

$$\#\boldsymbol{Operators\ needed} = \frac{\boldsymbol{Total\ cycle\ time}}{\boldsymbol{Takt\ time}} \qquad \textbf{2.15}$$

If enough waste can be eliminated in the process so that only the number of operators that are required can be used, the direct labour cost per part will be reduced.

To achieve consistent flow within the manufacturing value stream, the operators or workers must achieve consistent cycle times as well as produce to takt time. To achieve this, standardised work is used to set work procedures that will establish the best sequence and method for each assembly and manufacturing process. By implementing standardised work it provides a basis for consistently great levels of quality, productivity and safety.

The third stage of Lean application is levelling. *Heijunka* (load levelling) is a method used for planning and levelling customer demand. The levelling is based on the variety and volume of the manufactured product over the period of a shift or a day that is broken up into units. This method makes use of paced withdrawal that is based on pitch. With pitch calculated as shown in Equation 2.16. Paced withdrawal is a system used for moving small batches from one process or operation, to the next.

$$\boldsymbol{Pitch = Takt\ time \times Packout\ quantity\ or\ units\ per\ container} \qquad \mathbf{2.16}$$

2.6.2. Waste

Waste removal was pioneered by Toyota's chief engineer and is oriented to productivity rather than quality. As improved productivity leads to expose further quality and waste problems in the system, this leads to leaner operations (Hines *et al.*, 2005). The systematic attack on waste assists in identifying factors underlying fundamental management problems and poor quality (Hines *et al.*, 2005). There are three types of operations that are undertaken in an internal manufacturing context according to Monden (2012):

1) Non-value adding;
2) Necessary but non-value adding and
3) Value-adding.

Non-value adding operations involve unnecessary actions or pure waste, which should be eliminated completely. These operations include stacking intermediate products, waiting time and double handling (Monden, 2012; Hines *et al.*, 2005).

Necessary but non-value adding operations are necessary operations under the current operating procedure but may be wasteful. It includes operations such as unpacking deliveries, walking long distances to pick up parts and transferring a tool from one hand to another. To eliminate these types of operations, major changes need to be implemented to the operating system, such as arranging for suppliers to deliver unpacked goods or creating a new layout (Monden, 2012; Hines *et al.*, 2005).

Value-adding operations involve the processing or conversion of semi-finished products or raw materials using manual labour. It includes activities such as forging raw materials, sub-assembly parts and painting body work (Monden, 2012; Hines *et al.*, 2005).

The eight commonly accepted wastes are (Hines *et al.*, 2005):

1) Transport;
2) Waiting;
3) Overproduction;
4) Defects;
5) Inappropriate processing;
6) Unnecessary motion;
7) Unnecessary inventory and
8) Non-utilised talent.

Transport waste involves goods being moved, thus any movement in the factory could be viewed as waste. An attempt for transport minimization is usually made rather than total removal (Hines *et al.*, 2005). In addition, excessive movement and double handling are likely to cause deterioration and damage, as the distance of communication between processes increase and the time it takes to report poor quality to take corrective action is proportional (Hines *et al.*, 2005).

Waiting waste occurs when time is being used ineffectively. It occurs within a factory setting whenever goods are being worked on or are not moving. This waste affects both workers and goods as both spend time waiting. The ideal state when eliminating waiting waste is, consequent faster flow or movement of goods with no waiting required (Hines *et al.*, 2005). Workers' waiting time can be used for maintenance and training and should not result in overproduction (Hines *et al.*, 2005).

Overproduction is regarded as the most serious waste, as it discourages smooth flow of services and goods that are likely to obstruct productivity and quality. Overproduction is also likely to lead to excessive storage and lead times (Hines *et al.*, 2005). As a result, products may deteriorate, defects may not be detected early and artificial pressures may be generated on the work rate. The excessive work-in-progress stocks also results from overproduction, which leads to consequently poorer communication with the physical dislocation of operations (Hines *et al.*, 2005).

Defects are the bottom-line waste as it is direct costs. A philosophy of Toyota is that defects must rather be regarded as an opportunity to improve, than something that is traded off against what is poor management (Hines *et al.*, 2005).

Inappropriate processing waste is when complex solutions being found for simple procedures. For example, instead of using several small flexible machines, rather use a large inflexible one. The over complexity generally encourages employees to overproduce to recuperate the large investment made for the complex machines and discourages ownership (Hines *et al.*, 2005). Such an approach encourages poor layout that leads to poor communication and excessive transport. Therefore, the ideal is to have the smallest machine located next to subsequent and preceding operations that are capable of producing the required quality (Hines *et al.*, 2005).

Unnecessary motion waste involves ergonomics where operators must bend, stretch and pick up, when the actions could have been avoided. Such actions are likely to lead to quality problems and poor productivity as it is tiring for the employees (Hines *et al.*, 2005).

Unnecessary inventory waste tends to increase space and lead times, which prevents rapid identification of problems. Therefore, problems are hidden by inventory. Unnecessary inventory also creates significant storage cost that lowers the competitiveness of the value stream wherein the organisation exists. By reducing the inventory these problems can be corrected (Hines *et al.*, 2005).

The *non-utilised talent* or waste of human potential occurs when employees' experience, skills, and creativity are not utilised. This waste could occur when employees are not sufficiently trained and skilled employees are forced to conduct redundant work (Swan, 2017). By not engaging the worker's knowledge it is difficult to improve a process, as the people doing the work are more capable of identifying problems and solutions for them (Skhmot, 2017).

2.6.2.1. Process Activity Mapping

Process activity mapping is a technique that can be used for eliminating waste, irrationalities and inconsistencies and provide high-quality services and goods quickly, easily and inexpensively. This general approach has five stages (Hines *et al.*, 2005):

1) Study the flow of processes.
2) Identify waste.
3) Consider a better flow pattern involving different transport routeing or flow layout.
4) Consider whether the process sequence can be rearranged more efficiently.
5) Consider what would happen when superfluous tasks were removed and whether all the activities that are being done at each stage is necessary.

Process activity mapping involves the following steps: A preliminary analysis of the process is first undertaken, followed by a detailed recording of the items required in each process. The analysis results in a map of the process that is under consideration. The area or machine used for each activity as well as the distance moved, number of people involved, and time taken is recorded. A simple flow chart can be made of all the types of activities. Questions can then be asked in order to try and simplify activities, eliminate unnecessary ones, combine others in order to achieve sequence changes that can reduce waste (Hines *et al.*, 2005).

Section 2.6 contributes to understand how to implement Lean and identify waste for a company to be more productive. As a result, the throughput will be increased while costs will be saved, which ultimately results in an increase in efficiency and profit. This section indicates the areas of focus for a company to be leaner and thus also more competitive.

The discussion forms part of the quality and continuous improvement cornerstones of competitive advantage. The Lean concepts, namely cost reduction and flow, also further refers to the cost and pricing as well as the performance measurement competitive advantage's cornerstones. The following section on Value Chain provides an understanding on how to analyse a company's Value Chain and activities.

2.7. Value Chain

Over the years, the Value Chain Model has established itself in the product and service industry as one of the main models being utilised (Feller, Shunk and Callarman, 2006; Porter and Millar, 1985). The concept of a Value Chain has existed for many years but was famously promoted by Michael Porter in 1985. Porter first popularised and described the concept with regards to competitive advantage and manufacturing products (Feller, Shunk and Callarman, 2006; Porter and Millar, 1985). Since then the Value Chain concept has been applied and amended to other contexts such as network organisations and professional services (Rieple and Singh, 2010).

Porter defined "value" as, the price customers are willing to pay, for what the firm provides (Porter and Millar, 1985). The primary focus of a Value Chain is on the interdependent processes that generate value and the benefits that accrue to customers. Porter also used the concept value system for Value Chains that are linked between firms. In the present era greater collaboration and outsourcing of value creating processes between different firms exists, therefore the value system concept has more commonly been known as Value Chain (Feller, Shunk and Callarman, 2006).

The terms Supply Chain and Value Chain are often used interchangeably. Both supply and Value Chains are complementary views for extended enterprises with integrated business processes that enable the flow of services and products in one direction. A supply chain focusses on the flow of goods from suppliers to customer, thus, a downstream flow of goods. Supply Chains also consider broad business process integration along the chain of supply (Feller, Shunk and Callarman, 2006).

Value Chains flow in the opposite direction, with the customer being the source of value. Thus, value flows from the customer to the supplier in the form of demand (Feller, Shunk and Callarman, 2006). The primary difference between the two is a fundamental shift of focus from customer to the supply base. A distinction in defining value is to determine the exchange that generates value; determining whether it is between firms, business to business, or between firm and customer (Feller, Shunk and Callarman, 2006).

Kaplinsky and Morris's (2000) well known definition for a Value Chain is, the full set of activities that are required to bring raw material from a service or product through the different phases of transformation, production and delivery to the customer. A Value Chain is perceived to be equal to the sum of its parts by literature in production and environmental economics as well as ecological studies. Thus, it focuses on individual activities of the chain rather than the chain as a whole.

In logistics, engineering literature and supply chain management, the Value Chain approach refers to individual activities that affect the whole Value Chain (Beyers, 2017). The rapid increase in literature regarding facets of Value Chains makes it difficult to define Value Chains due to varying definitions (Lazzarini, Chaddad and Cook, 2001; Feller, Shunk and Callarman, 2006).

According to Porter and Millar (1985), the Value Chain is an important concept that emphasizes the role of information technology in competition. The Value Chain is a system of the company's interdependent activities that are connected by linkages, which exist when the performance of one activity affects the effectiveness or cost of other activities (Porter and Millar, 1985). Linkages can often create trade-offs that should be optimized in performing different activities. The management of linkages resolves trade-offs across the organizational line, which is often a powerful source of competitive advantage (Porter and Millar, 1985). Competitive advantage in either differentiation or cost is a function of the Value Chain that exists in a company.

The Value Chain is an accommodating model, as it can be applied at industry level, sector level or through a holistic approach. For industry–level analysis, costs are calculated at each stage of the process chain and are also aggregated across all the firms involved in the specific stage (Rieple and Singh, 2010).

The Value Chain concept is also key to understanding how services and inputs are brought together and then used to transform, grow, or manufacture a product; how value increases along the way as the product physically moves from the producer to customer (Beyers, 2017). Today, the Value Chain Model can assist industries in participating more effectively and efficiently. The main aim of the Value Chain is to move towards a holistic approach to achieve a competitive advantage by extending the line of sight. As a result, individuals work collectively within an organisation in cross-functional and multi-disciplinary teams (Feller, Shunk and Callarman, 2006).

2.7.1. Value Chain Analysis

Value Chain Analysis plays a key role in understanding the scope and need for systemic competitiveness. The identification and analysis of core competences will lead to identifying the firm's need for unique or distinctive functions. By mapping the flow of inputs in the production chain it allows a firm to determine other parties who play a vital role in its success. In cases where most of the firm's Value Chain operations are not internalised, its efforts to achieve efficiency and upgrade will have a negligible effect (Kaplinsky and Morris, 2000).

In the current era of rapid globalisation, Value Chain Analysis has become more important for the following reasons (Kaplinsky and Morris, 2000):

- With the growing dispersion of the production of components and division of labour, systematic competitiveness has become increasingly important.
- For successfully penetrating global markets, efficiency in production is a necessity.
- Global markets allow for sustained income growth when making the best of globalisation, thus an understanding of the whole Value Chain's dynamic factors is required.

Gereffi (1994), introduced the global commodity chain into the Value Chain literature. His contribution has enabled important advances in the normative and analytical usage of the Value Chain concept (Kaplinsky and Morris, 2000; Gereffi, 1994). The global commodity chain concept particularly focuses on power relations that are imbedded in the analysis of Value Chains.

By focusing explicitly on the coordination of production systems, which are globallly dispersed but linked, he has shown that chains are characteriesed by a dominant party (Kaplinsky and Morris, 2000). The dominant party determines the overall character of the chain and thus, the lead firm(s) become responsible for the coordination of the interaction between links and the upgrading of activities within individual links. This is a role of 'governance' and a distinction can be made between two types of governance; those in which the producers play a key role, 'producer-driven commodity chains', and those where coordination is undertaken by the buyers, 'buyer-driven commodity chains'

(Kaplinsky and Morris, 2000). By understanding the governance party, a better understanding of the competitive scope of a firm can be gained.

For any exchange of resources, where a comparison can be made between offers and competitive forces that affect the market, value is derived from customer needs. Thus, non-value-added waste is considered to be activities that do not contribute toward meeting these customer needs (Feller, Shunk and Callarman, 2006). Value is also layered at the customer level of exchange and can be described by three concentric rings, as depicted in Figure 2.14.

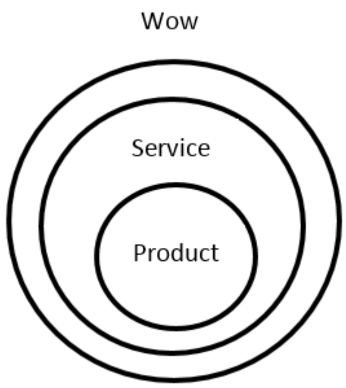


Figure 2.14: Customer value layers adapted from (Feller, Shunk and Callarman, 2006).

The *product value* in the centre ring is the derived value from providing a source of supply. The second ring, *service value*, is provided by services surrounding the product and includes services such as warranty service and customer care (Feller, Shunk and Callarman, 2006). The third ring, "wow" value, was made popular by business thinkers Waterman and Peters (1997) and has also been called new quality or service battleground. This level of value is achieved by providing services that would not only satisfy customers but "make your customer successful" (Feller, Shunk and Callarman, 2006). Thus, the product itself is secondary and the exchange of resources provides an experience with its own "wow" factor (Feller, Shunk and Callarman, 2006).

2.7.2. Value Activities

The value activities concept divides a company's activities that it performs to do business into economic and technologically distinct activities. The amount that buyers are willing to pay for products or services is the value a company creates (Porter and Millar, 1985). A company must either perform these activities in a way that would lead to differentiation and a premium price, or perform activities at a lower costs to gain competitive advantage (Porter and Millar, 1985).

As discussed in Section 2.2.1 all the value activities have certain costs associated with them. Therefore, it reflects the cost position of an company (Porter and Millar, 1985). A business is profitable when the value that the company creates exceeds the performing costs of their value activities. Thus, by reducing the value activity's costs and improving their efficiency, a higher total profit margin can be achieved (Feller, Shunk and Callarman, 2006).

Every value activity uses and creates information of some kind and has both an information-processing and a physical component (Porter and Millar, 1985). The information-processing component incorporates the steps required to channel and capture the data necessary to perform activities. It also greatly enhances the company's ability to exploit linkages. The physical component includes the physical tasks required to perform activities. An activity's information-processing and physical components may be simple or complex, as a different mix of the two components can be required for different activities (Porter and Millar, 1985).

A company's activities that are performed in different links in the chain, fall into two categories, namely primary and secondary activities (Porter and Millar, 1985).

- Primary activities: The activities involved in the creation of the product to create value to the product or service. It includes the delivery to buyers, marketing and support and servicing after sale.
- Support activities: Provides the infrastructure and inputs that allow the primary activities to transpire.

The primary activities consist of operations, inbound logistics, outbound logistics, sales and marketing, and service (Beyers, 2017). Operations include the activities required to store, collect and distribute the output. The inbound logistic activities refer to the activities that deliver services or products to the end customer. These activities include storage, collection and distribution systems that may be external or internal to the manufacturing firm (Beyers, 2017).

The outbound logistic activities include the activities involved in the distribution, collection and storage of the product. Sales and marketing refer to the activities that inform the buyers of the product itself as well as the benefits of the product. Finally, service includes the activities that are required to keep the service or product working effectively after it is sold and delivered to the buyer (Beyers, 2017).

For support activities, Porter (1985) identified four secondary activities: human resource management, technology development, procurement, and infrastructure. Human resource management consists of the activities involved in the recruitment, hiring, motivation, rewards, training and the retaining of workers. Technology development refers to the management and processing of technical knowledge (Beyers, 2017).

Procurement consists of the purchasing of resources and inputs for the firm (Beyers, 2017). Firm infrastructure supports the entire chain to maintain daily operations, it includes functions such as legal work, general management and accounting (Porter and Millar, 1985). Figure 2.15. illustrates the primary and support value activities.

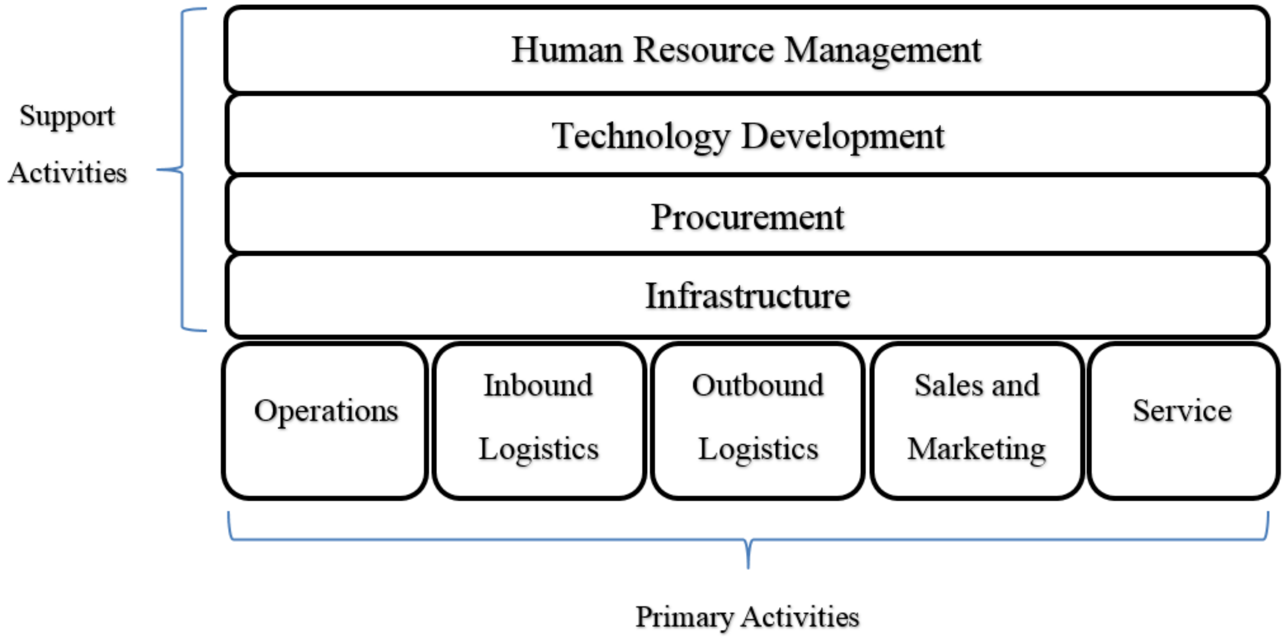


Figure 2.15: Value activities adapted from (Rieple and Singh, 2010).

For both primary and support activities, calculations must be made regarding the cost associated with the activity, as well as any increased value achieved. For primary activities it's often easier to determine the cost as it involves calculating the staff time, machinery costs, or raw materials involved in a specific production or design task (Rieple and Singh, 2010). It is harder to calculate the value added within an organisation, as before the product is passed to the next activity or stage, no price is calculated and for many activities little data is gathered (Rieple and Singh, 2010). The movement towards the Fourth Industrial Revolution addresses the problem of data collection as the focus is on real-time data collection. The movement, however, remains a challenge in South African manufacturing SMEs due to the adoption of Industry 4.0 technologies being hindered by different challenges, as discussed in Chapter 1.

The following sections on problem-solving methods and Assembly Line design provide an understanding of the different tools that can be used to identify problem areas to implement Lean. Thus, subsequent sections that follow are also part of the quality and continuous improvement competitive advantage's cornerstones

2.8. Problem-Solving Methods

This section investigates different popular methods used to identify and solve problems. A more in-depth study on the Value Stream Mapping (VSM) method is conducted as the use case required the use of this method to identify areas for improvement.

2.8.1. Root Cause Analysis

Root cause analysis (RCA) is a problem-solving method used to identify the root causes of incidents or problems (Hubbard, 2010). This method also helps to identify why an event occurred. Once the cause of the problem is identified, the appropriate steps can be taken in order to eliminate or solve the problem (James, Heuvel and Lee, 2004). The benefit of using RCA is that the identification of the root causes across the population of occurrences can then be used to target opportunities for improvement (James, Heuvel and Lee, 2004).

RCA can be used as a stand-alone analysis technique or form part of continuous improvement, such as Lean methodology (Jones and Despotou, 2016). The system-based approach associated with RCA is usually done as a team-based exercise. This method results in a range of identified root causes with regard to the same problem, which can be investigated to develop effective recommendations and to solve the identified problem (Jones and Despotou, 2016, Hubbard, 2010). By gaining expertise of the root causes this method can also be used as a pro-active method, by forecasting the occurrence of a problem before an incident actually occurs (Hubbard, 2010).

The process for performing RCA is sequential and comprises of the following steps (Jones and Despotou, 2016, Hubbard, 2010):

1. Identify the problem;
2. Organise teams to perform RCA;
3. Study the work processes;
4. Gather data;
5. Identify the true root cause that is associated with the problem;
6. Act by identifying effective solutions and
7. Evaluate the action taken to ensure effectiveness.

To conduct a RCA there are various techniques, the most popular methods is the 5Why and fishbone diagrams. The 5Why method involves repeatedly asking why, on average, 5 times or until no further information is obtained (Jones and Despotou, 2016). This method ensures that the reasoning behind the problem is critically explored (Jones and Despotou, 2016).

The 5Why approach promotes systematic problem solving through deep thinking (Serrat, 2017). To visually document the thinking process required by this process, a cause-and-effect diagram or also known as the Ishikawa or fishbone diagram, can be developed (Pojasek, 2000; Jones and Despotou, 2016).

The Fishbone diagram represents a model that shows the correlation between events and their multiple causes. The design looks like the skeleton of a fish with bevel line segments that lean on a horizontal axis. These lines illustrate the suggested multiple causes and sub-causes that produce the problem, as illustrated in Figure 2.16 (Doggett, 2005).

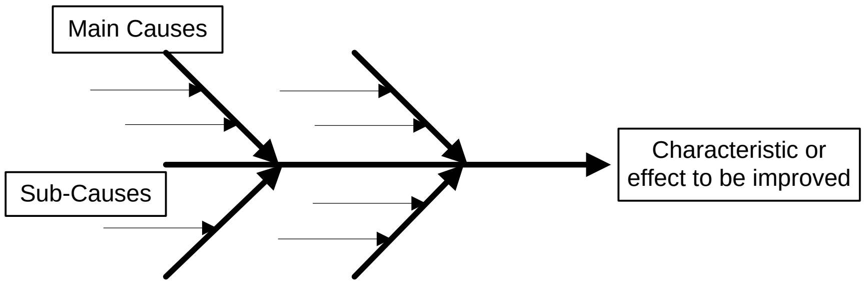


Figure 2.16: Cause-and-Effect or fishbone diagram adapted from (Doggett, 2005).

To identify the causes of problems the 5Why and fishbone methods can be used in combination. This is achieved by a structured approach which also encourages participation leading to group knowledge of the problem that is used to identify areas where data is required to solve the problem at hand (Ilie and Ciocoiu, 2010). These two methods are used as a mechanism to translate identified problems from a strategic level to a more tactical level (Pojasek, 2000; Jones and Despotou, 2016).

Although the 5Why technique used in combination with the fishbone diagram offers benefits, it has also been criticised of being a tool that is too basic for analysing the depth of the cause to ensure that the root cause is fixed (Serrat, 2017). Some of the reasons behind the critique are listed below (Serrat, 2017; Pojasek, 2000):

- Lack of facilitation and support: The facilitator needs some experience to help the investigators to ask the right questions.
- The application of the methods to large scale issues can be limited.
- To cast minds beyond current information and knowledge can be a challenge for investigators.
- Investigators can stop at the symptoms of the problem and not proceed further to the lower root cause levels.
- It can lead to finger pointing where one individual or group receives the blame for the problem or mistake.

2.8.1.1. 5W2H Method

The 5W2H method stands for 5 questions, What? Why? Where? Who? When? and 2 how-questions. The method was developed by Sakichi Toyoda, one of the establishers of the Toyota car company (Nagyova, Palko and Pacaiova, 2015). This method formed part of the TPS (Toyota Production System) initial training, as it is an essential method for problem solving.

The objective of the 5W2H method is to identify the cause and to facilitate the effective corrective and preventive action implementation. A team must respond to the 5W2H, What? Why? Where? Who? When? and How?, series of questions with no specific questioning technique required (Nagyova, Palko and Pacaiova, 2015). Table 2.4 shows some example questions by using 5WH2 for identifying a problem and its causes, and to implement improvements to solve a problem (Nagyova, Palko and Pacaiova, 2015; Veyrat, 2016).

Table 2.4: Example questions of 5W2H method.

	Problem	Improvement
5W	What is the problem?	What will be done?
	Why is it a problem?	Why will this be done?
	Where do we encounter the problem?	Where will it be done?
	Who is impacted?	Who will do it?
	When did we first encounter the problem?	When will this be done?
2H	How did we know there was a problem?	How will this be done?
	How often do we encounter this problem?	How much will it cost?

2.8.1.2. Problem-Tree Analysis

Problem-Tree Analysis (PTAs) addresses problems and their effects by relating the different factors that result from the core causes. Thus, the purpose is to find the link between the symptomatic factors (Doggett, 2005). The representation of the causes and the effects are shown in the form of a tree. The tree trunk shows the problem, the roots the causes and the branches show the effects or consequences. Similar to the 5Why analysis and fishbone diagram, the PTAs method also provides an overview of the issues or problems and whether they are the effect or cause of the issue or problem (Hewitt-Taylor, 2012).

The process is as follows: First the problem is identified, then the related problems are explored and recorded. After the issue is identified the guiding question is asked 'What causes that?' The PTAs method clearly shows the links between the different causes. It also provides broader overview, as multiple branches are used to illustrate the multiple effects of the problem. PTAs can also become challenging to manage too many links between the causes and effects (Hewitt-Taylor, 2012).

2.8.2. Value Stream Mapping

A Value Chain Analysis is a method of analysing and studying how value is added in different activities within an organisational setting. This method examines how these activities are coordinated and the costs of these activities. The aim of the analysis is to identify the areas of ineffectiveness or inefficiency through a systematic categorisation of the chain's activities and their associated costs (Rieple and Singh, 2010).

The areas where value can increase are identified by this approach. Value is increased through improving processes or enhancing linkages between organisational activities. Value Chain Analysis typically deconstructs the stages that a product follows from beginning of its production to the final sale. Where there are critical linkages between the various organisations the analysis includes distributors or suppliers of the product (Rieple and Singh, 2010).

VSM or analysis is a method used for business process improvements, by which Lean principles are applied to examine business processes. According to McManus and Millard (2002), VSM or analysis, can be defined as a method by which engineers and managers seek to increase the understanding of their company's development efforts for the sake of improving efforts. Most VSM to date has been done in the manufacturing industry (McManus and Millard, 2002).

VSM is a tool that focuses on the productive process' entire value stream, it maps an entire supply chain network or a productive process. The material flows as well as information flows that controls and signals production, are mapped out (Braglia, Carmignani and Zammori, 2011). A value stream perspective refers to a big picture perspective to improve the whole stream, therefore not just looking at individual processes to optimise the parts (Rother and Shook, 2003). The value stream consists of specific operational units along the Value Chain. For example, a specific processing plant, a specific farm, a specific retail outlet and a specific distribution centre. A Value Stream Map is used to document or map a process which provides value to an item (David and Andrew, 2009).

A value stream encompasses all the actions required to produce a product. The actions include both non-value added and value-added actions. A value adding process makes the final service or product more valuable to the end customer (Hines *et al.*, 2005). The value stream is mapped and analyzed in order to reduce waste in processes that also enables flow and move towards a process that is ideal for rapid response to customer pull. Therefore, in the product development context, rapid response for customer needs for adaptations and modifications of existing products as well as new products (McManus and Millard, 2002).

VSM can be used to identify waste in individual value streams to find an appropriate route to removal or reduction (Hines *et al.*, 2005). It is a tool that is used to support its associate analysis. Thus, it can be stated as a tool by which the outcomes of a value stream analysis are illustrated or depicted. The mapping of a process serves as a description of a highly complex real system in less complex 2-D format (McManus and Millard, 2002).

This simplistic format of the system facilitates understanding and insight that provides a common language used for communicating that insight. VSM has shown promise as a method that can be used for rapid, as well as low-cost improvements, of the product development processes (McManus and Millard, 2002).

The difference between the traditional value or supply chain and the value stream is the following: The value or supply chain includes complete activities of all companies involved, whereas the value stream only refers to specific parts of the firm that adds value to the specific service or product under consideration. Thus, a value stream is a more contingent and focused view of the value adding process (Hines *et al.*, 2005).

VSM offers several advantages and drawbacks when compared to other mapping techniques. The advantages are (Braglia, Carmignani and Zammori, 2011):

- It forms the basis for implementing Lean Production.
- It relates the manufacturing process internally to the facility of the whole supply chain.
- It displays both information and product flow.
- It links demand forecast and product planning to production scheduling as well as flow shop control.
- It ncludes information that are related to production time and to inventory levels.

The main drawbacks are (Braglia, Carmignani and Zammori, 2011):

- It is a paper-and-pencil-based technique, thus the accuracy level and the number of versions that can be handled is limited.
- Many companies are of high variety-low volume type. This means that several value streams are composed of hundreds of industrial products and parts. Thus, this complication cannot be addressed by using the standard method.

VSM can only be used effectively for productive systems that can be characterised by linear product routings. The application of VSM breaks down if the production processes are too complex, as it fails to map value streams that are categorised by multiple flows that merge. For products that are described by a complex bill of materials this typically happens (Braglia, Carmignani and Zammori, 2011). Rother and Shook (1999), suggested mapping only the key elements of the flow and also to draw one flow over another if necessary, in complex cases no decisional process has been proposed to choose the value stream's key elements (Rother and Shook, 2003).

These problems were first addressed in the technical literature in three different works. McDonald *et al.* (2002) applied VSM to a 'three parallel lines assembly process' to define the basic parameters for the future state map by using discrete event simulation (Mcdonald and Aken, 2002). By implementing simulation, they demonstrated that for the case of production complexity it can provide important information for the future state map implementation.

Following a similar approach, Lian and Van Landeghem (2002) mapped a 'two parallel line' push system (Lian and Landeghem, 2002). Respectively, for the push and pull system, two simulation models were built and key measurements such as throughput rates, lead times and value added ratios were evaluated, as well as compared.

Khaswala and Irani (2004) used a new mapping approch called value network mapping to improve a welding job-shop facility. This technique was derived from integrating the Production Flow Analysis, Simplification Toolkit and VSM (Khaswala and Irani, 2001). This approach was proven to support facility improvements in the current methods for material handling and manufacturing cells (Braglia, Carmignani and Zammori, 2011).

To map a value stream is relatively simple. The product's production path from the customer all the way through to the supplier is carefully drawn to make a visual representation of every process in informaton and material flow (Rother and Shook, 2003).

2.8.2.1. Value Stream Mapping Procedure

The following steps can be used for drawing a Value Stream Map: The first step is to draw the current state, this is done through gathering information on the shop floor and provides the information to develop a future state. The developing of the current, as well as the future states, are overlapping efforts, as the future state ideas come up while mapping the current state (Rother and Shook, 2003).

Likewise, when the future state has been drawn it will help identify important current state information that has been overlooked. The final step is to prepare a plan that describes how the future state will be achieved and to begin actively to impliment this plan. When the future state becomes a reality a new and improved future-state map should be drawn for continuous improvement (Rother and Shook, 2003).

To perform a value stream analysis Tapping *et al*. (2002) has introduced a step-by-step procedure. The selection of a product family, for the constuction of the current state map and as the target for improvements for the selected product value stream, is the first step (Braglia, Carmignani and Zammori, 2011).

To help decide which value stream(s) to target in order to implement improvements the following reliable methods can be employed if the customer has not defined the value stream (Tapping, Luyster and Shuker, 2002):

- Product-quantity (PQ) analysis: First a PQ analysis is done to determine whether some part numbers have volumes high enough to make the value stream choice an obvious one.
- Product-routing analysis: Used when the results from PQ analysis are inconclusive. In product-routing analysis the products or parts that have similar process routes are analysed to determine the value stream.

The current state map is based on a set of data that is collected directly on the shop floor. The standard icons shown in Figure 2.17 could be used to draw the current state map (Braglia, Carmignani and Zammori, 2011).

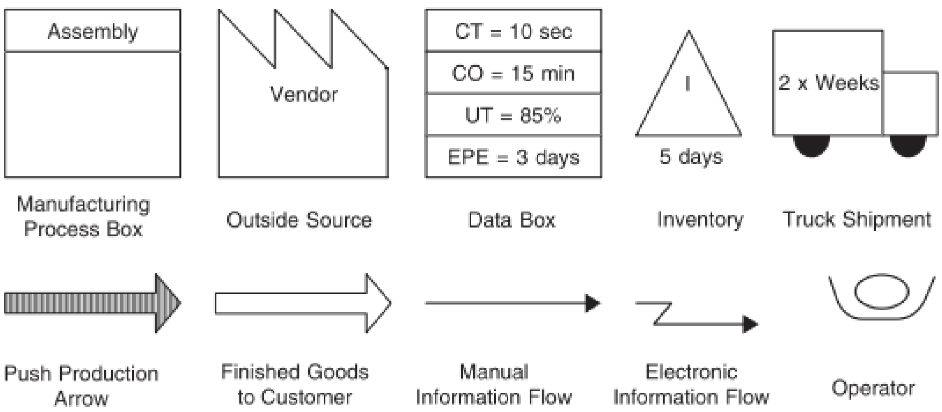


Figure 2.17: Actual state icons (Braglia, Carmignani and Zammori, 2011).

The next step is to identify and analyse the wastes that are encountered along the value stream. A future state map can then be designed without the removed wastes; thus, it represents the ideal production process. The following standard icons depicted in Figure 2.18 should be used to map the future state (Braglia, Carmignani and Zammori, 2011).

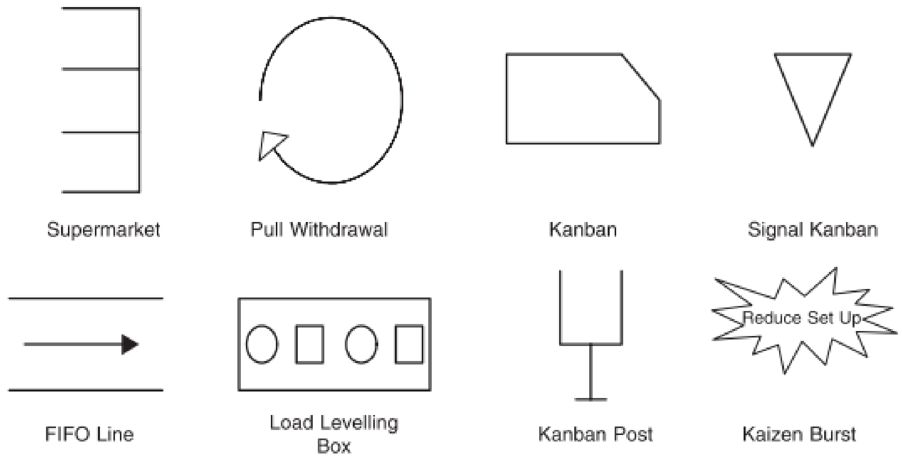


Figure 2.18: Future state map icons (Braglia, Carmignani and Zammori, 2011).

The future state map of how value should flow can be obtained by answering the eight questions listed in Table 2.5. The words *Heijunka* and *Kaizen* are both Japanese words; Heijunka means levelling and Kaizen refers to continuous improvement of personal efficiency and working practices (Braglia, Carmignani and Zammori, 2017; Rother and Shook, 1999):

Table 2.5: Design questions for future state map (Braglia, Carmignani and Zammori, 2011).

	Future state questions
Basic	1) What is the takt time?
	2) Will the finished goods be built and directly shipped to clients, or will they be built to replenish a supermarket?
	3) Is there a need in the Value Chain for a supermarket pull system?
	4) Where can continuous flow processing be utilized?
	5) What single point within the production chain can be used to schedule production?
Heijunka	6) How can the production at the pacemaker process be levelled?
	7) What increment of work will be released cosistently from the pacemaker process?
Kaizen	8) What process improvements will be needed?

2.8.2.2. Improved Value Stream Mapping Procedure

This section is based on an article by Braglia, Carmignani and Zammori titled "A new VSM approach for complex production systems". The improved VSM procedure, according to Braglia *et al.* (2017), follows an iterative procedure based on seven steps that are listed below (Braglia, Carmignani and Zammori, 2011):

1) Select a product family;
2) Identify machine sharing;
3) Identify the main value stream;
4) Map the critical path;
5) Identify and analyse waste;
6) Map the future state for the critical/sub-critical path and
7) Identify the new critical path and iterate the process.

The first step of the framework, 'Select a product family', consists of identifying the product families to select one as the initial target for implementing improvements. A product family is defined as 'a group of products that pass through similar steps in the process and over common equipment in the downstream processes. Thus, it is possible to group products into families through analysing the process and equipment being used (Braglia, Carmignani and Zammori, 2011).

The second step of the framework, 'Identify machine sharing', consists of identifying the machines that are being shared amongst more than one product family, which can act as a possible constraint for implementing Lean production. To achieve levelled and continuous flow, the layout of a facility must possess the following characteristics (Braglia, Carmignani and Zammori, 2011):

1) Flow paths in the cell should consist of smooth contours.
2) Flow is unidirectional with minimum cross-flows or backtracking between machines.
3) Flow takes place over short travel distances between consecutive pairs of operations.

The 'Identify the main value stream' step involves dealing with nonlinear production processes that are characterized by multiple flows that merge (Braglia, Carmignani and Zammori, 2011). When dealing with such processes, the improving and mapping of the whole process at the same time is usually not even feasible and not easy.

Thus, the mapping process should start with the main or critical value stream. Afterwards, the analysis should be extended to the other branches by following an iterative process. One of the main VSM objectives is to cut down the waste in progress. Moreover, the finished inventories need to be lessened and to reduce the time it takes for a piece to move through the whole process (Braglia, Carmignani and Zammori, 2011). Therefore, the critical path can be defined, according to Braglia *et al.* (2017), as 'the processing sequence which is responsible for the total production time that determines the minimum time frame needed to schedule production in advance'.

The fourth step, 'critical path mapping', consists of the construction of the current state map for the critical value stream. Data collection should follow the approach of Rother and Shook (1999), which begins at the shipping process and works backwards in the production process to suppliers or raw material as well as collecting data snapshots of inventory levels at each stage of the value stream (Rother and Shook, 2003). Since VSM has the unique feature of recording information flows that are associated with material flows, the following data should be collected (Braglia, Carmignani and Zammori, 2011):

- Machines: cycle time, set-up time, number of shifts or hours per day and number of operations.
- Production flow: production batches, inventory levels, shipping frequency, pallet dimension, average customer demand and type of flow between machines (push-pull).
- Information flow: forecast frequency, ordering frequency, time frame to plan production, system used to plan production, type of orders released to first tier suppliers, type of orders released by customers and time frame to plan production.

After all the data has been collected, the current stream map can be constructed using the VSM icons.

The fifth step, 'waste identification', consists of the analysis of non-value-added activities on the actual state map. Once the wastes and their respective causes have been detected, it can be determined whether the problems are concentrated in correspondence to the insertion points, or whether they are linked to the inefficiency that is spread among the whole critical stream. In order to determine the problems, it is useful to split each production station's downtime recorded into its main components: 'idle time', 'breakage' and 'lack of operator' (Braglia, Carmignani and Zammori, 2011).

The sixth step, 'main stream future state mapping', consists of the construction of the future state map for the critical value stream. It can be constructed by using the VSM icons and answering the eight future state questions as explained previously. Furthermore, part of the sixth step is secondary stream future state mapping. This sub step needs to be done when the main problems of inefficiency are located on a secondary branch (Braglia, Carmignani and Zammori, 2011).

Before attempting to make improvements on the main value stream, this branch must first be analysed. To do this, the approach described in Steps 4 and 5 should be followed to construct a current stream map of the secondary value stream. After the current stream map has been constructed, the cause of waste can be identified and a future state map can be derived to eliminate the critical path's inefficiencies (Braglia, Carmignani and Zammori, 2011).

The final step, 'process iteration', consists of applying the method to the other branches of the production process. To choose the next value stream as the target for improvements, the bill of materials needs to be modified in relation with the lead time reduction obtained by the modifications that were introduced in the process (Braglia, Carmignani and Zammori, 2011).

Through this way, it is possible to determine whether the new total lead time is determined by another value stream, or whether it is still determined by the main improved value stream. If the total production time is mainly determined by another branch, this branch becomes the new critical path. The procedure then starts from Step 4 again. Thus, the productive process's various branches proceeding can be analysed by following a structured iterative process which eventually comes to an end, when the total production time of the process cannot be reduced further (Braglia, Carmignani and Zammori, 2011).

The above section further provides an understanding of the problem-solving methods and an in-depth review on Value Stream Mapping, which were used to map the Biltong Factory's Value Stream Map to identify the area in the chain that should be focused on for improvement. The next section discusses the importance of performance measurement as another procedure or tool that can be used for implementing Lean by tracking performance.

2.9. Performance Measurement

Performance measurement is critical to improve a company's effectiveness and efficiency. Decision-makers in a company focus on developing measurement metrics or key performance indicators (KPIs) to evaluate performance (Cai *et al.*, 2009). KPIs embody a strategic objective that measures the performance against the goal. These goals can be multidimensional, as they serve a different purpose for different authority levels (Eckerson, 2009).

KPIs can either be output KPIs or driver KPIs. The output KPIs measure the output of past activities, while driver KPIs measure the performance of the activities that influence the outcome. Driver KPIs are viewed as more powerful, as adjustments can be made based on the KPIs in order to still achieve the desired objective or goal (Eckerson, 2009).

The following sub-sections are aimed specifically at the manufacturing industry. The sections discuss how performance measurement can be used in assembly line design, as well as how cycle time and Methods Time Measurement (MTM) can be used to measure performance.

2.9.1. Assembly Line Design

The objective when designing an assembly line is to balance the line to distribute the total workload as evenly as possible. The work needs to be spread amongst the workers to ultimately improve the line performance. The following are some considerations that need to be taken into account when designing an assembly line (Groover, 2015).

The *line efficiency* is a critical factor in an assembly line operation. The following steps can be taken to ensure that the line does not stop: The first step is to minimize downtime occurrences by implementing a preventative maintenance programme (Groover, 2015). Secondly, a well-trained repair crew can be employed to fix breakdowns quickly when they occur. The third step is to manage the incoming components to ensure that part shortages do not cause line stoppages. The last step is to insist on high quality parts from suppliers to ensure that downtime is not caused by the components' poor quality (Groover, 2015).

If a particular operation at one work station results in a bottleneck, while the adjacent work station has ample idle time, the bottleneck and idle time might be solved by *sharing the work elements* between the two adjacent stations (Groover, 2015).

Preassembly of components can reduce the amount of work that is done on the regular assembly line and can be prepared offline, either by purchasing the components from a vendor that specializes in the required processes or by another assembly cell. Some reasons for organizing the assembly operations in this way include (Groover, 2015):

- To implement the required process on the regular assembly line may be difficult.
- The associated assembly operations task time variability could also result in a longer overall cycle time when done on the regular assembly line.
- Lastly, an outside vendor with certain specialized capabilities or a cell setup in the plant could achieve higher quality.

Storage buffers between stations refers to a location where units are temporarily stored in the production line, which could generally improve the performance of the production line by increasing the line efficiency. Some reasons to implement one or more buffers for storage include (Groover, 2015):

- To smooth the production between different stations that have large task time variations.
- To accumulate the work units when the production rates are different between two stages of the production line.
- The final reason is to permit continued operation of sections in the line while another section is down temporary for repair or service.

Parallel workstations are used to balance a production line. It can be applied when a station's long task time causes the line's production rate to be less than that required to meet the product demand. Therefore, in this case the bottleneck may be eliminated by two workstations, both performing the same long task, operating in parallel. In some situations, the advantages of using parallel workstations are not as obvious (Groover, 2015).

2.9.2. Methods Time Measurement

To determine the cycle time, Monden (2012) and Harry *et al.* (2010), state that industrial engineering techniques, such as time and motion studies, can be used. Frederick W. Taylor, also known as the father of scientific management, first measured the performance of his workers and established operation times or production levels from previous performance records. In the development of work measurement his next step followed the example of M. Coulomb who used a stopwatch, around 1760, to determine the time needed to perform a certain operation. After Taylor began his work, Mr. Frank B. Gilbreth made detailed laboratory studies of methods and motions before developing the Micromotion Study procedure (Karger and Bayha, 1987).

The two different viewpoints were known as the Time Study and Motion Study approach. However, they eventually found that their approaches only differed a little, which led them to combine the best features of both approaches into what is known today as "Methods Engineering" (Karger and Bayha, 1987).

According to Kanawaty (2006), method study is a critical examination and systematic recording of ways to do things in order to implement improvements. The terms work simplification, operation analysis, work design, corporate reengineering and methods engineering are frequently used synonymously. These terms all refer to techniques that can be used to decrease the cost per unit output or to increase the production per unit and productivity improvement.

To seek out ways in which an activity can be done in less time, with less effort, and with greater effect, the study of human work activity through methods analysis can be applied. *Methods Time Measurement* (MTM) can be used to define the work element in order to balance the line and to examine workstations which turn out to be or cause the bottleneck. The analysis may result in a better workplace layout and improved efficiency of workers' motions. Moreover, the analysis could lead to the design of special fixtures and/or tools to facilitate manual work elements or in changes of the product design for easier assembly (Groover, 2015).

Due to methods engineering, by implying the utilization of technological capability the productivity improvements are never-ending (Freivalds and Niebel, 2014). When establishing accurate time standards, the possibility exists to increase the efficiency of the operating personnel and the equipment. Poor established time standards can lead to labour dissension, high costs and even possibly, the failure of the enterprise (Freivalds and Niebel, 2014).

One of the steps in developing an efficient work centre is to establish time standards. These standards can be determined by using historical records, estimates, and work measurement procedures. The historical record method uses records of similar jobs performed previously, to determine production standards (Karger and Bayha, 1987). Although analysts relied on estimates in past years, experience has shown that fair and consistent standards cannot be established by an individual by simply looking at and making a judgement on the amount of time required to complete it (Karger and Bayha, 1987).

Work measurement techniques represent a better way to determine fair production standards or the actual allowed time standard needed for performing a given task. These measurement techniques include: stopwatch time study, standard data, predetermined time systems, work sampling studies or time formulas. The equipment required to conduct a time study include a time study board, stopwatch, pocket calculator, time study forms, and video equipment can also be very useful (Freivalds and Niebel, 2014).

Zandin and Maynard (2001) also mentioned that for establishing the cycle times, the usual practice to make measurements is by using a stopwatch. According to Kanawaty (2006), using a stopwatch for time studies is an essential piece of equipment. Kanawaty (2006), also defines time studies, as a technique used for recording the time it takes to perform a specific job or its elements. These jobs are carried out under certain specific conditions, and for analysing the recorded data to obtain the time required for an operator to carry out the work at a defined rate of performance.

2.9.3. Cycle Time

The elapsed time for an activity from start to completion is called the cycle time (Harry *et al.*, 2010). It can also be defined as, the time for any production operation that one work unit takes to be processed or assembled. The cycle time is the time between when the one work unit begins with processing or assembly, until the next unit begins (Groover, 2015).

The total cycle time can be calculated once the cycle time has been established for each production activity. By taking the sum of the cycle times for all the activities in the process in the value stream, the total cycle time or total manufacturing cycle time is calculated (Harry *et al.*, 2010; Chincholkar and Herrmann, 2008). Within that period there is a multitude of discrete activities each having their own cycle time (Thomas, 1990). Conclusively, to determine the total cycle time there must exist well-determined cycle times for both the value-added and value-enabling activities.

Cycle time is a measure of efficiency, as stated in Section 2.2.4. Possible potential benefits of determining process cycle times can include (Nadarajah and Kotz, 2008):

- Increased throughput;
- Reduced costs;
- Streamlined processes;
- Schedule integrity;
- Improved on-time delivery;
- Reduced process variability and
- Improved communication.

To calculate the performance efficiency, the cycle time is multiplied by the parts that are produced in total, and then divided by the actual operating time (Puvanasvaran, Mei and Alagendran, 2013). For re-engineering processes for improvement, it is necessary to access the process cycle time (Termini, 1996). Therefore, the cycle time also influences the overall factory effectiveness, efficiency and the takt time (Oechsner *et al.*, 2003; Zammori *et al.*, 2012).

The cycle time is made up of operation time, set-up time, loading/unloading time and machine idle time (Han, Lee and Choi, 2013). It can be defined as the sum of two variables, namely the busy time and idle time. The busy time is the time during which a unit is worked on or acted on to bring it closer to the desired output. Idle time, on the other hand, is the time during which a unit is waiting to be worked on or to take the next action (Nadarajah and Kotz, 2008). Groover (2015) also mentions that the cycle time can be broken up as a proportion of cycle when a part is being processed (operation time), a proportion of cycle time when a part is actually being handled (handling time), and on average there is a proportion of cycle time when adjustment and change of tooling is being done (tool handling time). The two main components of cycle time can be summarised as:

- Run time: The time of actual processing or assembling operation (Groover, 2015).

- Miscellaneous Time (MT): Indicates the time of an action which is not a run action. It contains actions such as, foreign elements; elements which are not part of the operation being studied; occasional elements; elements that does not occur in each work cycle, but may occur at irregular or regular intervals (Kanawaty, 2006).

A summary of the above cycle time literature is depicted in Figure 2.19.

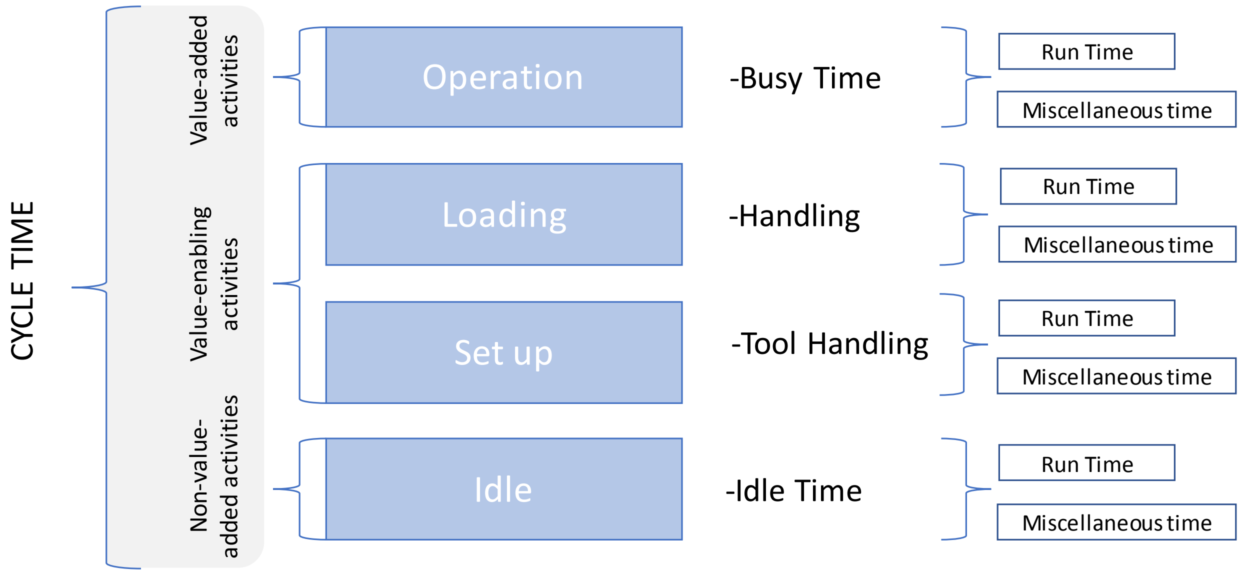


Figure 2.19: Activity cycle time components.

The previous section provides an understanding of different assembly line design concepts that can be used to balance the line to distribute the total workload evenly. This section also explores methods for time measurement, a method that can be used to increase the efficiency of the operating personnel and the equipment.

Lastly, cycle time was discussed as it can be used to contribute to improving performance measurements. This section also indicated that time studies are a technique that can be used to measure the cycle time to implement improvements. Although, it was previously stated that this section forms part of the quality and continuous improvement cornerstones this section also forms part of the performance measurement competitive advantage cornerstone.

2.10. Use Case Analysis Methodology

A use case analysis methodology was developed, based on the reviewed literature. The methodology can be used to guide the process of analysing an use case. This methodology is illustrated in Figure 2.20.

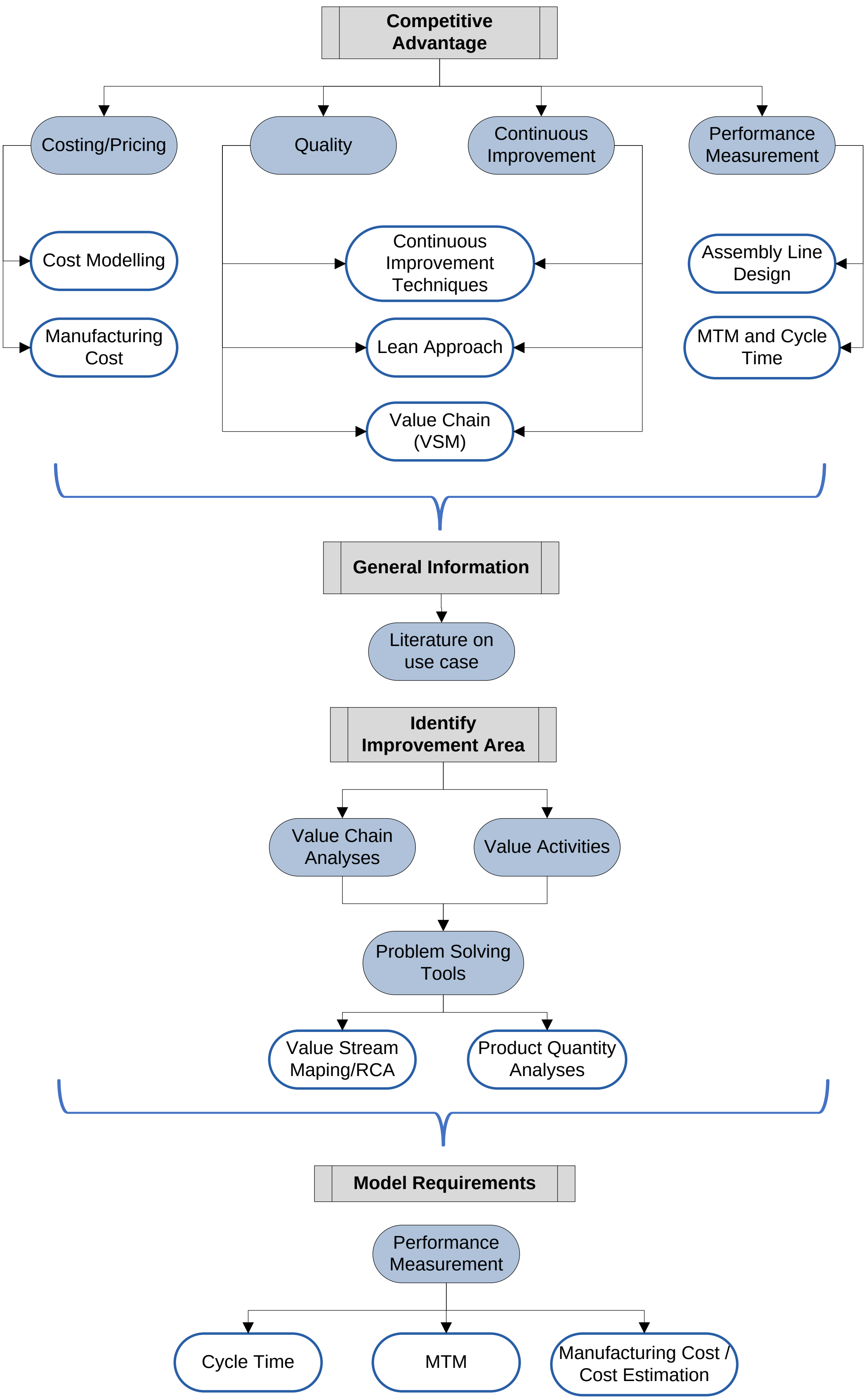


Figure 2.20: Use case analysis methodology.

The first phase is to understand the competitive advantage concepts of an use case. The four cornerstones that were identified in Figure 2.1 (cost and pricing, quality, continuous improvement, and performance management), can be used to assess the competitive advantage of the use case. The first cornerstone, cost and pricing, was investigated by conducting research on manufacturing costs and cost modelling. For continuous improvement and quality, different continuous improvement techniques were analysed. Furthermore, research was conducted on the Lean approach as well the tools that are implemented in support of Lean. These tools included Value Stream Mapping (VSM) and Root Cause Analyses (RCA). Aspects of performance measurements, namely assembly line design, MTM, and cycle time were also investigated as part of the performance measurement cornerstone.

The next phase is to conduct literature on the use case to understand the use case for the analysing phase that follows. The next phase will be to analyse the factory's Value Chain and its value activities. This information is then used to further analyse the factory by using a problem-solving tool in order to identify the area that requires improvement. The next step will then be to determine what performance measurement data is required for the improvement tool aimed to be developed.

2.11. Chapter 2 Summary

In this chapter, various concepts of manufacturing were investigated. Additionally, competitive advantage concepts and tools were reviewed, including cost and pricing, quality, continuous improvement, and performance measurement. These cornerstones were further investigated by reviewing literature on the types of manufacturing costs and cost modelling, continuous improvement techniques, Lean approach, Value Chain, problem solving tools, and performance measurement.

From the different continuous improvement techniques that were analysed, it was stated that there are clear similarities to the Lean approach. For this reason, further research was conducted on the Lean approach. Some Lean concepts, such as cost reduction and flow, are closely related to the costing or pricing, as well as the performance measurement cornerstones of competitive advantage. Process activity mapping was also identified as a tool to eliminate waste.

In conclusion of this chapter, some of the previously mentioned concepts that were regarded as important elements for analysing a use case were aggregated to develop the use case analysis methodology depicted in Figure 2.20. The information provided in Chapter 2 will, therefore, be utilised to: (i) analyse the factory to determine an improvement area; (ii) determine the data required to develop the production management model and (iii) establish the function of the production management model.

Chapter 3

Use Case Analyses

This chapter[2] is primarily concerned with the use case analysis. The Activity Based Costing (ABC) method is discussed in detail as it is used, in conjunction with the use case analysis methodology presented in Chapter 2, to guide the process of analysing the use case. Background information on biltong is also presented in this chapter. This background information is used to assist with analysing the Biltong Factory to identify the focus areas for possible improvement. Different concepts that were reviewed in Chapter 2 are applied to analyse the Biltong Factory to identify an area that would have a significant improvement impact on the Biltong Factory. By identifying the area in the Biltong Factory that is in need of improvement, the production management model can be developed for the specific part or area of the factory. The contents of this chapter forms part of the continuous process that is discussed in Section 1.2.3. This continuous process was followed to achieve the main goal of this study, i.e. developing a generic approach to increase manufacturing SMEs' competitiveness.

3.1. Analysing the Use Case

In order to guide the process of analysing the use case, the Activity Based Costing (ABC) application steps, as described by Ray and Gupta (1992), are used. These ABC application steps are subsequently discussed.

3.1.1. The ABC Method

ABC is the collection of operational performance and financial information that is related to significant activities of the business (Ray and Gupta, 1992). ABC systems focus on activities as the fundamental cost objects, the costs for each activity are accumulated as a separate cost object, then it is applied to products undergoing the different activities. The basis used for the allocation of applying costs to the products are called the cost drivers, which includes causal factors that influence the total costs of the activity. Cost drivers can be both volume-related and volume-unrelated allocation bases for applying costs to products (Chan, 1993).

The ABC method assumes that activities causes costs and that products consume those activities, thus, activities drive costs (Steward *et al.*, 1995). Within the ABC system, the cost is traced to

[2] A large portion of the contents of this chapter was published in the 29th South African Journal for Industrial Engineering (SAJIE) in 2018. Attached in Appendix G.

activities before it is traced to products (Ray and Gupta, 1992). The basic principle is that cost units should tolerate the cost associated with the activity they cause (Gowthorpe, 2005).

The application of ABC includes the following (Ray and Gupta, 1992):

1. Identify activities.
2. Distinguish between value-added and non-value-added product/service activities.
3. Trace the product/service flow sequence through activities.
4. Assign cost and time values to activities.
5. Determine linkages between activities within and across functions.
6. Make the flows more efficient; make trade-offs between activities where net savings are possible; reduce non-value-added activities.
7. Continuous improvement.

Among the many benefits when implementing ABC, is improved decision making and better cost control (Chan, 1993). Groover (2015), states that ABC can result in substantial improvements in the quality of information, thus also resulting in better control and planning of production.

Consequently, the ABC method is an appropriate method to use to guide the process of analysing the use case. The following table indicates in which sections of Chapter 3-5 the ABC application steps was conducted:

Table 3.1: The application of the ABC steps in this research.

ABC Application	Section
1.) Identify activities.	3.3.1 3.3.2
2.) Distinguish between value-added and non-value-added product/service activities.	3.3.2
3.) Tracing the product/service flow sequence.	3.3.2 3.5.3
4.) Assign cost and time values to activities.	4.3 5.1
5.) Determine linkages between activities within and across functions.	3.3 3.4 3.5
6.) Make the flows more efficient; make trade-offs between activities where net savings are possible; reduce non-value-added activities.	4.2 4.3 5.1
7.) Continuous improvement.	5.1

The final step of the ABC application, namely continuous improvement, was initiated with the developed production management model for the use case. For further improvement projects it remains the Biltong Factory's responsibility.

As described earlier, the ABC applications steps were used in conjunction with the use case analysis methodology presented in Figure 2.20 to analyse the use case, and to develop a production management model for the Biltong Factory.

3.2. Biltong Background

This section explores the biltong market size and manufacturing process to provide an understanding of the market and processes associated with the biltong industry. This section also reviews food supply chains and the biltong Value Chain to assist with the use case analysis.

Biltong and *droëwors* are popular, traditional high-value snacks in South Africa. The popular snack is also enjoyed by consumers worldwide. Often comparisons are made with other dried-meat products such as charqui, carne seca, carne do sol (South America), and beef jerky (North America). However, biltong differs in its taste, production process and end-product characteristics (Strydom and Zondagh, 2014).

The origin of the word biltong is derived from Dutch, *bil* refers to the animal's posterior thigh or meat and *tong* refers to the tongue-shape fillet or strips (Petit *et al.*, 2014; Strydom and Zondagh, 2014). Biltong made its way to South Africa as the *Dutch settlers* dried their meat strips while they trekked across the continent (Strydom and Zondagh, 2014). Initially, biltong was mainly made from springbok meat. Today a variety of species are used: kudu, beef, springbok, impala, wildebeest, ostrich, chicken and lately even pork (Strydom and Zondagh, 2014; Naidoo and Lindsay, 2010).

Beef is the most popular specie used for biltong manufacturing today. Biltong is made of meat that is cut into strips of desired size, seasoned with spices and vinegar, and then it is dried with hot air. On the other hand, *droëwors* are hot-air dried sausages (D'Amato *et al.*, 2013; Naidoo and Lindsay, 2010).

The process of making biltong is standard and is manufactured at a variety of levels. From large-scale factories for industry, to small-scale butcheries, family businesses or manufacturing at home for self-consumption (Beyers, 2017; Strydom and Zondagh, 2014). Although the manufacturing steps stay the same, the large-scale production and small-scale family business market differ in the type of technology used, as well as the quantity produced. Thus, resulting in a mixed market of unbranded and branded products (D'Amato *et al.*, 2013).

Small-scale businesses typically use fans for drying and produce around a tonne of dry product per month. Industrial level companies use specially designed chambers for drying and produce an estimated 30 tonnes of dry product per month (Beyers, 2017). The price drivers in the biltong industry include the popularity of the meat used, the cost of the animal and the cost of processing (Saayman, 2015).

3.2.1. Food Supply Chains

Food manufacturing can be defined as 'the series of processes that link the raw products from farmers to food products for consumers' (Johns, 2017). Food manufacturing industries transforms livestock and agricultural products for final or intermediate consumption. The industry groups process raw materials (generally from vegetable or animal origin) into food products. These food products are typically sold to retailers or wholesalers to distribute the end product to the consumers (North American Industry Classification System (NAICS), 2018).

Lazzarini *et al*. (2001), refer to the cooperation and interconnection between systems as a 'net chain'. They defined the 'net chain' as a directed network of actors that cooperate to bring a product to the customers (Lazzarini, Chaddad and Cook, 2001). In food supply chain networks more than one business process and more than one supply chain can be identified, both sequential and parallel in time. As a result, organisations can play different roles within the different chain settings. Thus, they collaborate with differing chain partners that may also be competitors in other chain settings (van der Vorst, Tromp and Zee, 2009).

Due to the presence of multiple autonomous functions, organisations and people within a dynamic environment, supply chain networks are complex systems. Food supply chains are comprised of organisations responsible for the distribution and production of vegetable or animal-based products and can be distinguish into the following two types, fresh agricultural products and processed food products (van der Vorst, Tromp and Zee, 2009).

1) Fresh agricultural products: Fresh fruits and vegetables. The chains may be comprised of auctions, growers, importers and exporters, retailers and speciality shops, wholesalers and their logistics service suppliers. The main processes are the packing, handling, storing, transportation and trading of food products.
2) Processed food products: Include products such as portioned meats, desserts, snacks and canned food. The chains may be comprised of importers, growers, food industry processors, out-of-home segments and retailers and their logistics service suppliers. In these chains the agricultural raw material products are used to produce consumer products with higher added

value. Due to the conservation processes the consumer products are sometimes hardly perishable.

Food supply chain networks have specific product characteristics that impact the redesign process. According to van der Vorst *et al*. (2009), the characteristics include the following:

- Variable process yields in quality and quantity due to seasonality, variation and random factors connected with pests, weather and other biological hazards.
- Seasonality in production requiring global sourcing.
- Requirements for conditioned storage and transportation means.
- Keeping quality constraints for finished products, intermediate products, raw materials as well as quality decay while products move through the supply chain. As a result, the chance for product stock-outs and shrinkage exists in retail outlets when the product quality has declined too much and/or the best-before-dates have passed.
- Due to environmental and quality requirements and product responsibility, it is a necessity for traceability of work in process.

The following four unique characteristics distinguish agri-food chains or food chains from other Value Chains. These characteristics are (Beyers, 2017):

1) Vulnerability: Food products are closely tied to the life cycle of animals and plants as well as to the natural environment. For this reason, the agri-food or food Value Chain is influenced by factors that are beyond the control of the stakeholders in the chain.
2) Dependence: In developing countries, a large part of the economy is represented by food Value Chains that many people derive an income from.
3) Inclusivity: Everyone is part of the food Value Chain, as all consumers’ well-being is directly affected by the food they eat. Consumers have a great impact on the nature of the food Value Chain through consumers’ preference, habits, residential location and concerns.
4) In relation to the above, the quality of food products is thus difficult to control in terms of preservation and uniformity over time. Physical factors such as, humidity, light and temperature control the quality throughout the food chain. Food safety and quality are vital measures of efficiency along these types of Value Chains and can be measured through a food loss analysis.

3.2.2. Market Size

Biltong is considered a healthy and convenient "go-to" snack food and has therefore become a popular consumer choice (Buys, Minnaar and Nortje, 2005; Dzimba, José De Assis and Walter, 2007). Due to the convenience of snack foods, the consumers have increased their consumption of these type of foods. Researchers have noted that these trends need to be taken advantage of by the food industry, by expanding and developing product lines to meet the average customer's current needs (Carr *et al.*, 1997; Miller *et al.*, 1988; Fuller, 2011).

Currently in SA there is no official annual estimation of biltong production. Van der Riet (1982), stated that over 100 tonnes of biltong was produced annually in the 1980s by several producers in SA, with the total biltong production estimation closer to thousands of tonnes (Van der Riet, 1982). In 2003, Gull Foods, a company producing biltong in SA, produced 6 to 16 tonnes per month (Attwell, 2003). Closwa biltong, the largest biltong manufacturer in Namibia, produced up to 660 tonnes per annum in 2015, while Cape Deli, a Cape Town manufacturer, produced 480 tonnes of product per annum (Jones, 2017).

In the South African diet, biltong has become a regular commodity over the years. In 2003, the annual biltong market value was roughly estimated at R640 million to R1.1 billion (Petit *et al.,* 2014). According to Saayman (2015), a paper from North-West University reported biltong sales to be in excess of R2.5 billion in 2015. Sales of beef biltong constituted R2.4 billion, while Game biltong constituted R237 million (Saayman, 2015). This is understandable as biltong and *droëwors* are sold everywhere in South Africa. It can be bought unpackaged or packaged from specialised biltong shops, butcheries, upscale supermarkets, pharmacies and even hardware stores (Saayman, 2015). With the sales growth of biltong, the efficiency in the different Value Chains of meat producers will need to be analysed if producers want to deliver quality and safe products to consumers (Beyers, 2017).

In the international market, biltong has gained popularity – specifically in Namibia, Australia, United Kingdom, New Zealand, Canada, United states of America and a few countries in Europe (Netherlands, Denmark, and Switzerland). Some are beginning to sell biltong through stores that supply products that are traditionally South African and through internet sites. South African biltong producers are experiencing difficulties to export products due to "virtually non-existent opportunities for export without an European Union and HACCP (Hazard Analysis Critical Control Points)-certified factory" (Attwell, 2003). The consumer demand for consistency and quality and the high cost of raw meat is a problem for both international and South African markets alike (Jones, 2017).

3.2.3. Biltong Manufacturing Process

To understand the manufacturing industry of red meat, the following four unique characteristics need to be taken into account (Beyers, 2017):

1) Carcass imbalance: Specific meat cuts have a rare balance resulting in an unpredictable and unsustainable supply downstream.
2) Product disassembly: A whole animal carcass unit is split into a variety of finished products that each have their own demand and price.
3) The dominant position of the South African supermarkets within the red meat supply chain: The power extent that supermarkets use in order to decrease prices for processors as well as farmers, has a great influence on the South African red meat industry.
4) Long animal production lead times: Lead time can be defined as the time it takes for a specific activity within the Value Chain, to start and finish. Animal production is much longer than the great majority of other food industries.

Biltong production involves a several steps, which include meat preparation, spicing/salting, and drying. The meat selection that can be used for biltong are beef, game, ostrich, chicken, and lately even pork (Strydom and Zondagh, 2014; Naidoo and Lindsay, 2010). The muscles that are the most popular to use for biltong are the topside (*semimembranosus*), silverside (*biceps femoris*), eye of round (*semitendinosus*), thick flank (*rectus abdominus*), and fillets (*longissimus dorsi*) (Van Wyk, 2007; Strydom and Zondagh, 2014; Van Tonder and Van Heerden, 1992). See Appendix A for more detail on the different cuts.

3.2.3.1. Meat Preparation

The biltong process starts with preparing the meat by cutting it in the desired shape. The connective tissue is removed when cutting the meat and the resulting meat is then cut into long strips. This is commonly done by hand, but large-volume modern processors often use specially designed rotating circular blades as well as mechanical de-membraning machines. The dimensions of the strips depends on the muscle type as well as personal preference; suggestions include a thickness of 2.5-5 cm and 25-40 cm length, thicker strips has longer drying periods (Van Tonder and Van Heerden, 1992).

Biltong can be fatty (with layer of fat on surface) or lean (with no fat on the outside), which are both popular amongst consumers. However, it is recommended to trim the excess fat from the meat as this may cause rancidity (Strydom and Zondagh, 2014). While beef biltong may contain some fat, game species and ostrich seldom have excess fat, therefore, produce lean biltong (Strydom and Zondagh, 2014).

3.2.3.2. Spicing or Salting

The traditional method for spicing/salting the meat is layering the strips and spicing each layer. After each layer is spiced with the preferred ingredients, the meat is stored at ambient temperatures, nowadays also in a cold room of 4-8 °C. After 6-12 hours, the meat strips are turned over and left for another 6-12 hours before they are ready to be hung for drying (Van Tonder and Van Heerden, 1992).

Tumbling is used at large scale biltong manufacturers to help with the mixing of the ingredients. By using this technique under low vacuum, the time of the spicing/salting process is substantially reduced. Tumbling is used to accelerate the food production process as it accelerates salt diffusion and enhances the juiciness and tenderness (Toldrá, Mora and Flores, 2010; Hui, 2012). During the tumbling operation the meat pieces fall and hit paddles in a rotating drum, which causes cellular disruption of the meat tissue that allows a more evenly distribution of the spices/salt (Toldrá, Mora and Flores, 2010).

One of the disadvantages is that when tumbling is performed at great speeds it could lead to certain quality issues such as mechanical damage, heat production, and poor salt distribution. Consequently leading to lower or poor-quality products (Toldrá, Mora and Flores, 2010). Some of the advantages of using tumbling machines in biltong manufacturing include limited hand contact with meat and less handling of large quantities of meat. Thus, processing time as well as costs are reduced by increasing output yields and the tumbling process also promotes the distribution of spices/salt and vinegar more uniformly within the meat (Jones, 2017).

3.2.3.3. Drying

The traditional method of drying biltong is to hang the meat strips by hooks (plastic or wire) outside in shady areas for one to two weeks. The duration depends on the ambient temperature. In winter time the wind and humidity conditions are considered ideal (Van der Riet, 1982). This method of drying, as well as drying the meat in a small box equipped with a light and a fan, is still used at a household level.

These methods were adapted to a commercial level as the demand increased for biltong. A variety of equipment at commercial level, has been used for the drying process (Van der Riet, 1982). Methods include to equip a room with heaters and fans to control the drying chamber units. In industry the dryers are mostly temperature controlled but some can also measure/manipulate the relative humidity (Strydom and Zondagh, 2014).

The drying of biltong is commonly done at low temperatures of 25 - 30°C and dried to 50% weight loss (Strydom and Zondagh, 2014). The following changes that occur due to the drying may be of concern. "Case hardening" or surface crust formation is when the outside meat surface is hard and dry but the inside of the meat is still very moist (Duan *et al.*, 2011; Bellagha *et al.*, 2007). "Case hardening" can occur when high drying temperatures are used, and/or high air velocity with low relative humidity. This results in a shorter drying period and causes a high drying rate. Thus, the moisture loss from the surface of the meat is high and when the surface is too dry the moisture within the meat would not evaporate quickly enough (Duan *et al.*, 2011; Bellagha *et al.*, 2007).

Biltong can be packaged in different ways. Butcheries in SA mostly sell biltong in plastic wrapped trays or paper bags. Industrially produced biltong products are packaged in vacuum-packed/nitrogen-flushed packaging to give the product a longer shelf-life. Vacuum packaging is not suitable for biltong with high moisture as it causes it to stick together (Van der Riet, 1982; Strydom and Zondagh, 2014).

One of the new packaging technologies in the food industry is modified atmosphere packaging (MAP) or controlled atmosphere packaging (CAP). These technologies adapt the atmosphere inside the packaging so that the composition is other than that of air (Day, 2008). Two MAP technologies commonly used in the biltong industry are compensated vacuum gas flushing and gas flushing.

Compensated vacuum gas flushing is a two-stage process, first the air is removed from the package by a vacuum followed by gas flushing, where the package is flushed by the modified gas composition (Jones, 2017). For oxygen-sensitive products this method is more suitable. Gas flushing flushes the air out of a package by using a continuous gas stream. This method leaves a residual oxygen level of 2 – 5% inside the package, thus making this method unsuitable for foods that are sensitive to oxygen (Jones, 2017).

3.2.4. Biltong Process Losses and Value Chain

A study conducted by Beyers (2017) identified three types of process losses that can occur in the manufacturing of biltong or *droëwors*, they are:

1) Pre-process loss: Occurs when the raw meat enters the secondary processors where it is trimmed and prepared. This type of process loss is associated with the quality of the meat bought from the primary processors and includes losses such as sinew and blood loss. These losses are purchased by the processor but cannot be transformed into biltong. Therefore, it is categorised as a pre-process loss.
2) Process loss: Occurs when the products are discarded after the drying and packaging process due to the product being unsuited for selling. The product can be inconsistent as pertaining to production specifications or it can contain spoilage factors.

3) Post-process loss: Occurs when the quality of the product, after it has been sold, decreases due to degradation such as discolouration and spoilage such as mould.

These process losses can be associated with each stage of the biltong Value Chain. Figure 3.1 illustrates the biltong Value Chain from 'primary producers' to 'consumers'.

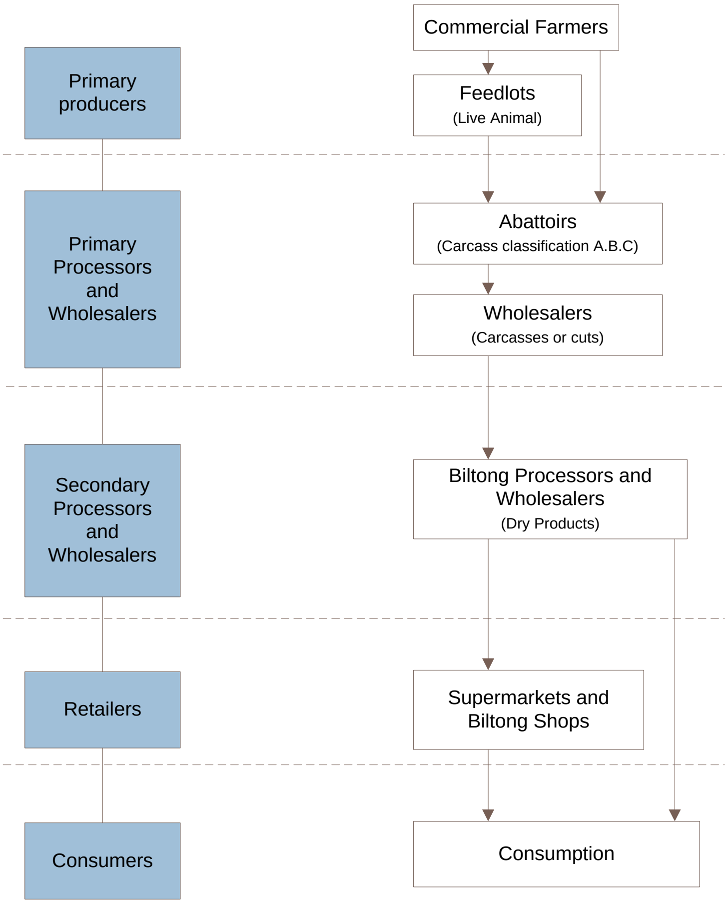


Figure 3.1: Beef/Biltong Value Chain adapted from (Beyers, 2017).

At the "Secondary Processors and Wholesaler" Value Chain stage, the following losses take place: Pre-process loss occurs when the wet processing is done, i.e. when the process of cutting biltong pieces and the spicing process takes place. Process loss occurs when the biltong and *droëwors* drying process is undertaken as well as during the packaging and storing of the product.

At the "Retailers" and "Consumers" Value Chain stages, post-process loss occurs when the storing and handling of the products is undertaken. Hence, at the "Secondary Processors and Wholesaler" stage food loss occurs before the product reaches the end-user (pre-consumer food losses) and after reaching the end-user, due to the consumers discarding the product (post-consumer food waste).

When determining the food loss in the biltong industry the question to consider is: What is the main problem that causes biltong and *droëwors* losses? According to Beyers (2017), mould growth is the most common problem in the biltong industry and is undesirable by consumers. Therefore, it results in economic losses for retailers as well as the secondary processors.

The above section provides an understanding of the biltong industry and production. The background presented in this section is used to assist in analysing the use case. This section also further discussed food supply chains and illustrated the biltong Value Chain from 'primary producers' to 'consumers'. The Value Chain provides information required to classify the phase in the biltong Value Chain, which the Biltong Factory being used in this study is part of.

3.3. Biltong Factory Value Stream

According to Rother and Shook (1999), a value stream perspective means to take a 'big-picture' perspective to improve the whole stream. Therefore, before identifying the gap for possible improvement or addressing the problem that this study aims to achieve a big-picture perspective needs to be undertaken.

The segment in the biltong Value Chain (from primary producers to end consumer) which the Biltong Factory is part of, is identified as the 'secondary processors and wholesalers' phase, as highlighted in Figure 3.2.

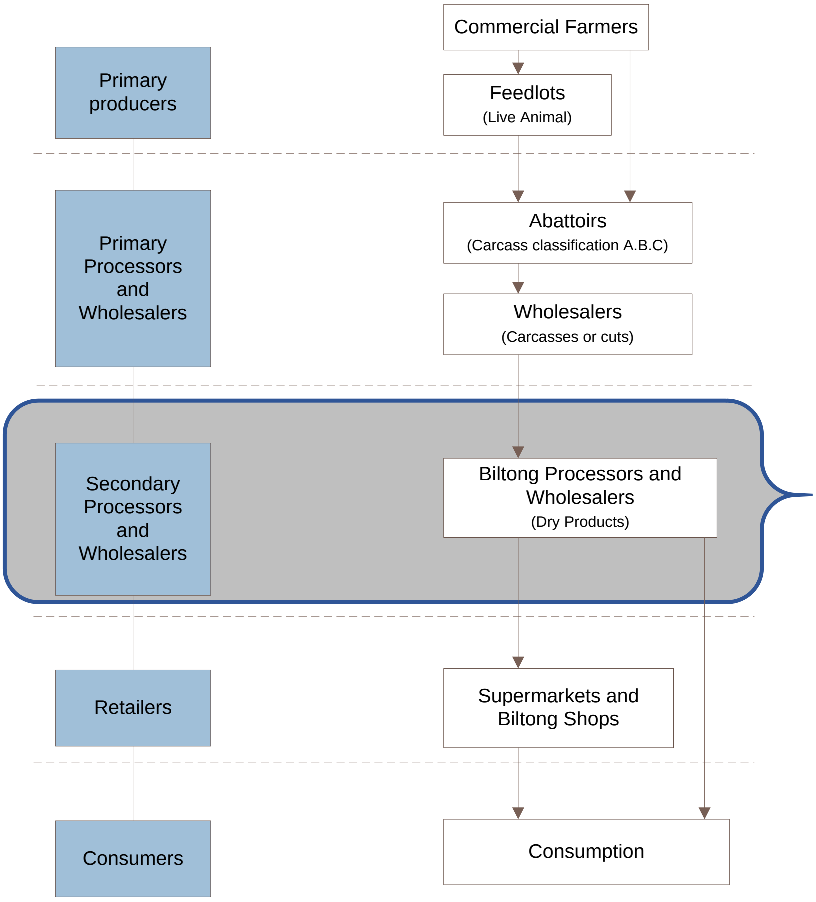


Figure 3.2: The use case phase within the Beef/Biltong Value Chain adapted from (Beyers, 2017).

3.3.1. Factory Processes

The Biltong factory that was used in this study has two separate factories namely the 'Wet Factory' and 'Dry Factory'. The different processes of the two factories were first analysed in order to develop a Value Stream Map of the Biltong Factory.

The 'wet factory' handles the processes involved to prepare the cuts of meat before being dried. The 'dry factory' operates the managing, drying and packaging processes to prepare the product before sending it to the various customers. Figure 3.3 and Figure 3.4, depict the process maps of the wet and dry factories respectively.

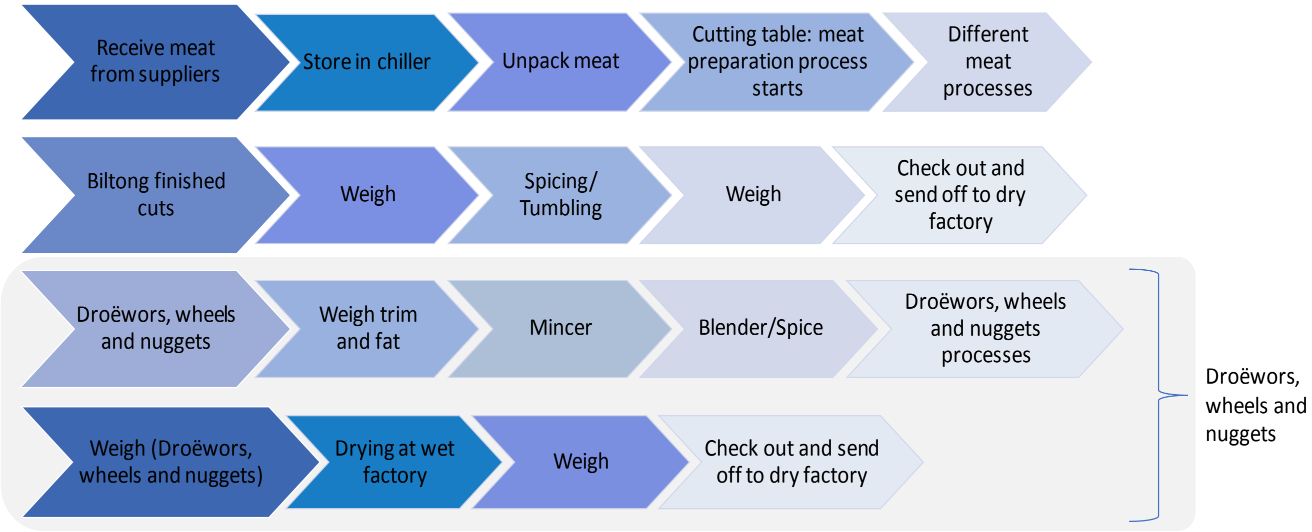


Figure 3.3: Process map of 'Wet Factory'.

In Figure 3.3, the meat is received from primary processors (see Figure 3.2), as the factory receives cuts of meat from the suppliers. These suppliers are also the primary producers of the meat, as they have their own feedlots to ensure consistent quality. The factory only buys meat from suppliers that have their own feedlots to provide a consistent good quality product to their customers. The quality of the meat bought can also minimize pre-process loss as discussed under Section 3.2.4.

Before the meat goes to the cutting table, where the process starts for the variety of products, the vacuum packaging is first removed from the meat to drain the blood from the meat cuts. The meat cuts are then prepared/cleaned at the cutting table before they move to the different processes to produce the final raw meat product. Two of the outputs at the cutting table are trim and fat, which are used in the products that are made from minced meat, such as the *droëwors*, wheels and nuggets.

The processing of the biltong varies depending on the type of product as well as the customer requirements. For example, a customer can require a certain thickness of the biltong or choose between fat or without fat. Unlike the biltong cuts the *droëwors*, wheels and nuggets are dried at the 'Wet Factory'. When the drying process is complete, these finished dried products are then sent to the 'Dry Factory' for packaging and distribution. The other biltong products are dried at the 'Dry Factory', thus the spiced wet biltong products are sent to the 'Dry Factory' for drying as well as packaging and distribution. Figure 3.4 illustrates these 'Dry Factory' processes in more detail.

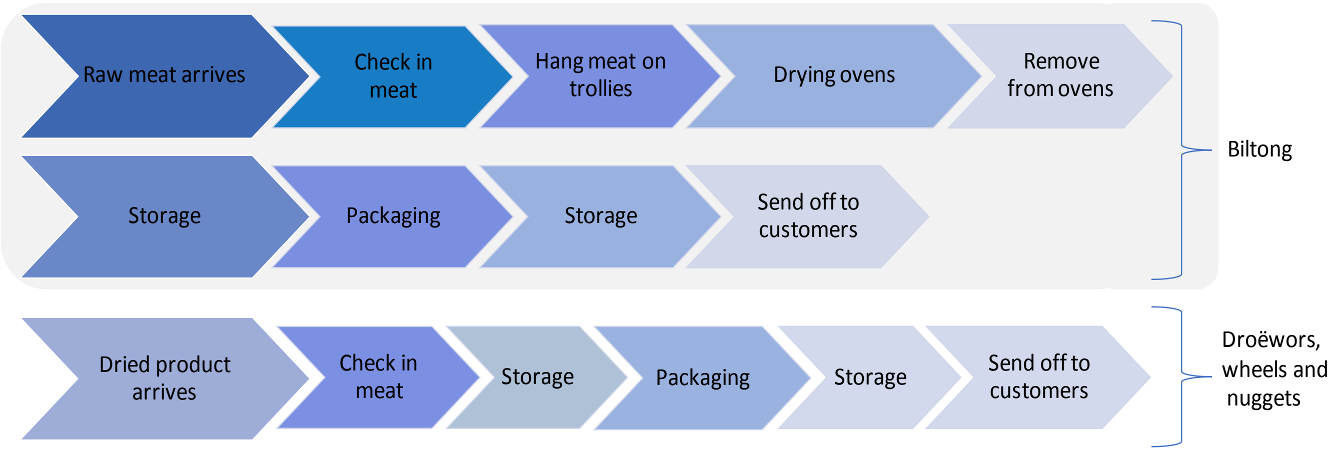


Figure 3.4: Process map of 'Dry Factory'.

Once the meat from the 'Wet Factory' arrives at the 'Dry Factory' the biltong products are dried according to customer specifications; as some customers prefer more dried biltong than others. The drying process is regulated strictly due to the impact it can have on the profit margins as the products are sold per kilogram. For example, if the biltong is over dried the meat loses too much weight. The expenses or cost for all processes remains the same but the product now weighs less than planned for. Therefore, the company loses money or can even make a loss on the product. The different products are packaged by machines that use specific materials to ensure long product shelf life. The packaging is done according to customer specifications, which includes labels, weight per package and the type of packaging material used. After the packaging process is completed the products are ready to be distributed to the different customers, which ranges from small biltong shops to large retail stores.

3.3.2. Value Stream Map

The Value Stream, as described in Section 2.6, is the set of actions or activities that bring the product from raw material to finished goods, order to delivery, or concept to realization (McManus and Millard, 2002). The Value Chain, as described in Section 2.7 also focusses on the customer being the source of value (Feller, Shunk and Callarman, 2006). Thus, the value stream, as described in Section 2.8.2, refers to the specific parts in the firm that adds value to the product. It provides a more contingent view of the value-adding processes. Therefore, the value stream differs from a supply or Value Chain that includes activities of all companies involved (Hines *et al.*, 2005). The VSM was developed based on the literature review, in Section 2.8.2, as well as information that was collected directly from the Biltong Factory after an understanding of the processes as discussed above, in Section 3.3.1, was undertaken. The VSM in Figure 3.5 uses the actual state icons, depicted in Figure 2.17, to map the value stream of the whole Biltong Factory, including both the 'Wet Factory' and 'Dry Factory' activities.

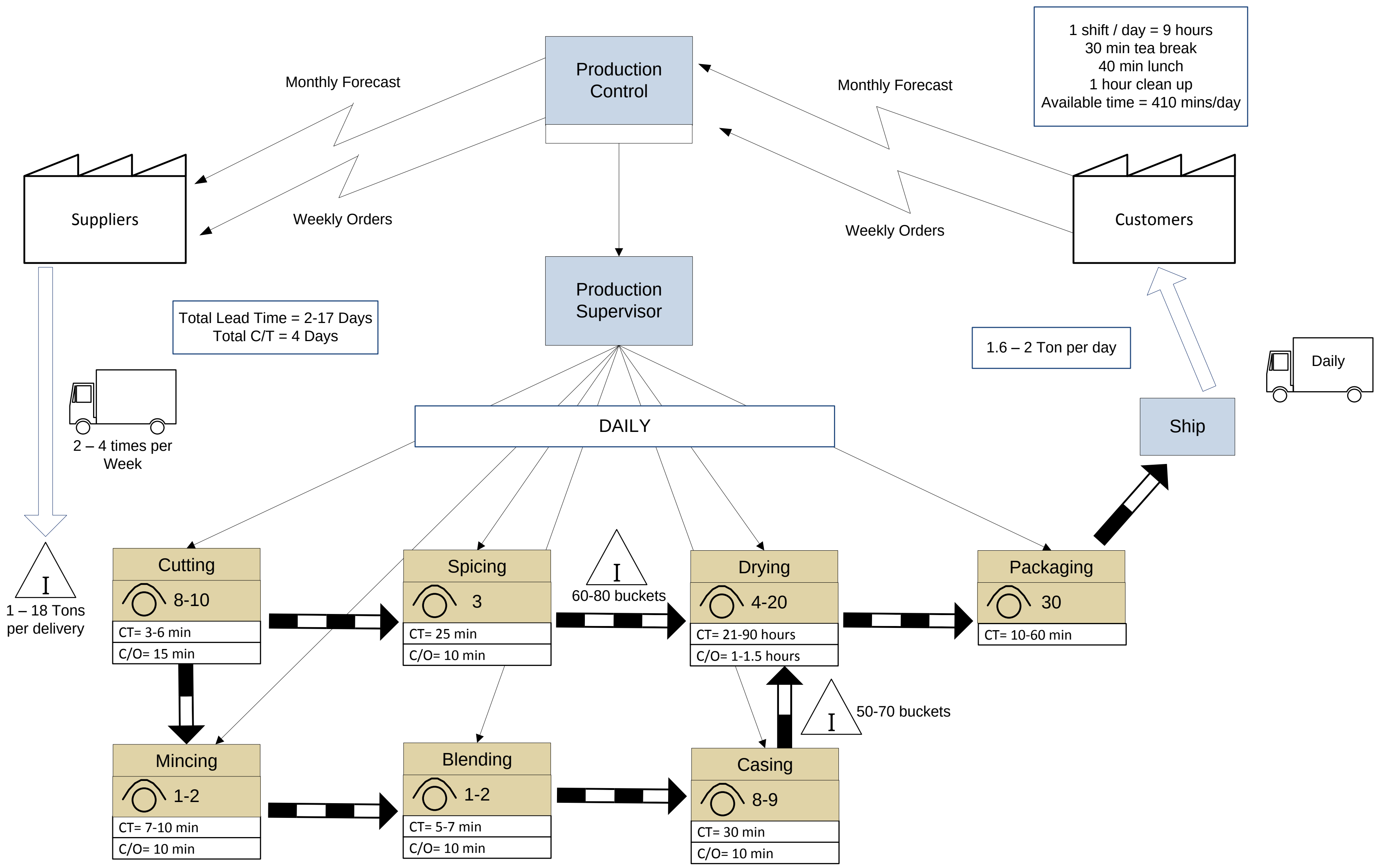


Figure 3.5: Value Stream Map of Biltong Factory/Use Case.

The information depicted in the VSM in Figure 3.5 will be analysed further in the subsequent section. In the right-hand corner, internal information about the production time per resource available per day is shown. The shift per weekday is normally from 07:00-16:00 but can vary to as much as 4 hours longer per day, which is from 07:00-20:00, depending on sale demands. This is normally before long holidays or occasions like December holiday or Father's Day. The factory also sometimes operates on weekends if the longer hours are still not enough to cover the high demand. The workers have tea time at 09:00 for 30 min and lunch at 12:00 for 40 min. The factory ends off each day with a deep clean from 15:00-16:00, to ensure that the factory is clean for the next day's operations. By considering tea time, lunch and cleaning time the actual available production time per day for one shift is 410 min/day (6 hours 50 min per day).

The production control department receives electronic information based on monthly forecasts and weekly orders from customers. Electronic information is then fed to the suppliers by the production control department based on the monthly forecast and weekly orders from customers. This information is reported to the production supervisors, who do daily manual monitoring of the different tasks involved in converting the raw materials to a finished product. The workforce is divided between the dry and wet factory as follows:

Table 3.2: Wet and Dry Factory workforce division.

Number of workers	Description
Wet Factory	
Total: 44	Works directly with meat
Dry Factory	
Total: 118	
94	Works directly with meat
8	Admin
11	Sales
2	Food safety
3	Directors

The suppliers ship inventory 2-4 times per week to the production unit, where manufacturing is performed. The deliveries vary from 1 ton to 18 tonnes. The Biltong Factory has ±50 different suppliers. These suppliers supply raw meat cuts, spice and packaging material to the Biltong Factory.

The lead time of different products differs, which is the time from when an order was made till the order is received. The lead times differs depending on the product and quantity ordered. For raw meat cuts, 3-4 days, spices 1-3 days and for packaging the lead time can differ as much as 1 day to 2 weeks.

The striped arrows between the different processes (shown in Figure 3.5) indicate how the materials are pushed from the one process to the other in the stream of processes. Under each process the number of operators required per process as well as a data box that captures the cycle time and change over time per process, are depicted. The cycle time is based on the process time per bucket, thus to complete ±60 kilograms. The change over time for each process includes the time to clean stations, machines and drying units between different batches. For each process the changeover times include the following:

- Cutting process: Cleaning of workstations is required between batches of different meat types like game and beef.
- Mincing, spicing, blending and casing processes: The machines and workstations are cleaned when the spice mix is changed for a new batch as well as between different meat type batches (beef to game).
- Drying process: The change-over time is the time it takes to clean a whole drying unit after a batch has been dried.
- Packaging process: Change overs occur when the weight per packet, logo and type of material needs to be changed.

All the processes depicted in the VSM are important for the company. If these value stream processes are not done correctly the customers can send their products back and/or the company can lose money. The following explains how these processes depicted in the VSM add or create value for the customer.

The cutting process, depicted in Figure 3.6, is important in order to meet customer requirements, as the customers can require a certain thickness of biltong. This process also adds value to the customer, as the process can influence the quality of the product. For example, if the cutting of the meat cuts is not done correctly the meat can still have sinew and/or too much fat attached.

The cutting process is very important regarding creating value for the company because, if it is performed with poor precision, the company's profit margin will be reduced. When excess meat is cut off as trim or fat while preparing the biltong products, the factory loses money on the end products, as trim and fat are part of the minced products. Minced products generally have a lower market value than the biltong products, even though both products originate from the same cut of meat.

Figure 3.6: Cutting process start of meat preparation (photo taken in the Biltong Factory that is analysed in this study).

The mincing process creates value for the customer as the customer can require a certain fineness of mince and they can choose a mince recipe (percentage fat and trim). For the spicing and blending processes, the customers can also choose a certain spice mix that is part of the Biltong Factory's recipes. Therefore, these processes also add value for the customer. For the casing of the sausage the customer can order a specific length of sausage and they can choose from two different casings used for the *droëwors* products namely, artificial and natural casing.

During the drying process the meat loses a minimum of 55% of its original weight. The time required for the drying of the biltong products are dependent on the type of product being dried, the weather conditions (cold and/or wet weather requires longer drying time) and the customer's requirements. This process also creates value for the customers as the customers can order a certain wetness or dryness of their products.

The drying process is carefully monitored as it is the most crucial process in creating value for the company. If the products are dried excessively the company can lose a lot of money as there is now less kilograms to sell to customers. Each drying unit takes several tonnes per unit at a time for the drying process, between 3-5 tonnes (50-80 buckets at an average of 60 kg per bucket). The number of buckets is shown in the VSM as inventory pileup before the drying process, as this process can only start when a drying unit is loaded full of meat. Due to large batches that are dried in the same drying unit concurrently, the loss can be immense for the company when the drying is done incorrectly.

The final process, namely packaging, also depends on the customer requirements and can vary from the type of material to different customer logos being used to package the products. When packaging is complete the end product is pushed for shipment to the different customers.

The Biltong Factory supply's products to ±1000 customers. These customers vary from small biltong shops to big retail stores. The lead time to complete an order received on a weekday but does not form part of the weekly forecasted orders are: Requests for packets is 48 hours and for bulk orders the order can be ready on the same day or within 24 hours. The turnaround time for bulk orders is shorter as they are not packaged in special packaging and are put together in big plastic bags.

The daily shipment of products varies from 1.6-2 tonnes. The delivery lead time differs as follow. For local deliveries around 100 km away, the Biltong Factory does the deliveries themselves and the order is shipped once the order is ready or complete. For customers that are located further away the deliveries are done by couriers. The lead time can differ for workdays; 24 hours to courier around 400 km away and between 48-72 hours to further locations.

The total lead and cycle time summarises how long it takes to complete an order from the time the order has been received. The total lead time to complete varies between 2-17 days, however, the average cycle time is 4 days to complete. The lead time of 17 days is for extreme cases when full customisation is required from a customer, and/or when all the required material is not available to complete an order, and/or the suppliers is out of stock.

This section provides an understanding of the company's two separate factories namely Wet and Dry factory. By analysing the processes, a VSM for the Biltong Factory was developed. The information discussed in this section is used for a further analysis of the factory's business operations.

3.4. Business Use Case Analysis

The following section will further investigate the Biltong Factory's operations that were introduced in the previous section, through the Biltong Factory process maps and VSM.

3.4.1. Classify Production

By analysing the Value Chain and using the literature discussed in Section 2.1, the production types used at the Biltong factory can be classified. The Biltong factory is part of the Secondary industry, as the factory converts the primary industry outputs (meat) into products (biltong and *droëwors*).

The factory being investigated uses *batch* production. Between different types of meat (batches), for example beef and chicken or different spice batches, cleaning of work stations/changeover needs to take place. Although this is only a quick interruption in the production, the factory does need to be changed over or cleaned to produce the next batch, therefore it can be classified as batch production

The product variety of the Biltong Factory can be classified as a *soft* product variety. The factory has a variety of products that are dependent on the customer requirements. For example, different spice flavour, thickness of Biltong and the type of meat. Although the company has a variety of products, the manufacturing processes that the products must go through and the equipment being used to manufacture the products are similar.

The production layout used in the factory can be categorized as *cellular manufacturing* or *flow-line production*. The Biltong Factory uses cellular manufacturing, as it is typically associated with a soft product variety and the variety of biltong products are manufactured using the same equipment. The production layout can also be classified as flow-line production, as the biltong manufacturing process involves a sequence of workstations, which the meat must move through in order to complete the product.

3.4.2. Business Processes and Price Policies

The Biltong Factory's orders are forecasted based on historical data from their regular customers. The historical forecasts make it possible for the factory to make provision for the customer's order even before the actual order is received. For example, when the customer puts their order in on a weekly basis the factory already knows the average total of the customer's order, therefore, they already made provision or started to produce their order to be ready for shipment in the same week.

The Biltong Factory handles orders in this manner, as orders have a certain lead time for receiving the raw material or meat and to go through all the processes. The factory always produces extra products to cover unexpected orders that were not forecasted. For example, customers can request an order to be delivered on the same day. With the extra produce the Biltong Factory are able to deliver the unexpected order. Although the factory manufactures extra products, they still do not produce too much biltong, as they end up in most of the cases, with no extra inventory.

The order instruction from the 'Dry Factory' to 'Wet Factory', or the kilograms of dry products required to cover orders, are done on a weekly basis. The operation control workers at the 'Dry Factory' determine the total amount of wet product required for a week to meet the end product or dry product demand required by customers. The sale's price per kilogram is constant for all the different products, therefore, the wet and excessive dried products have the same price per kilogram. The wetness or dryness influences the amount of product the customer receives, as more wet biltong weighs more than the same size of more dried biltong.

The big customers, like retail stores, do however get a discounted price. The discount is a form of commission given to these big retail stores as they bring large amounts of business to the Biltong Factory. This type of commission is discussed in Section 2.2.1. Many businesses provide discounts on selling prices to reward customer loyalty. The supplier's profit margin is reduced by a small margin through providing such discounts however, it is usually balanced out by a commensurate benefit, as these customers ensures significant amount of business leading to guaranteed sales (Gowthorpe, 2005). Therefore, prices of the Biltong Factory do differ from the standard price for big retail stores but there is still a price basis.

3.4.3. Use Case Business Environment

The business environment for the Biltong Factory will provide an understanding of the internal and external factors that affect how the company functions. The business environment of the Biltong company can be divided into Internal, Micro and Macro-environments. The Internal environment refers to the variables inside an organisation over which the management roles have control. The Micro-environment comprises of the industry factors which influence competition. Lastly, the Macro-environment reflects the influence society can have on the business (*Business Environment-infogram*, 2018).

Based on the information provided in Chapter 3 thus far, the following business environment illustration was developed to indicate the factors that influences the Biltong Factory:

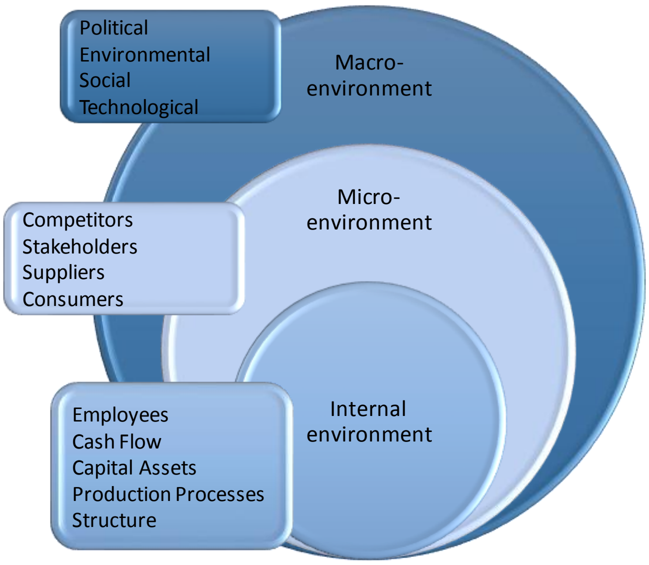


Figure 3.7: Use Case Business Environment adapted from (Business Environment-infogram, 2018).

The Macro-environment can influence the use case's business in the following way: Political factors can influence the cost and market of the company. The cost can be influenced by the government deciding to increase property tax, thus the factory's expenses will be greater. The market can be influenced by the government if they decide that rugby will be banned in SA. As it is part of the culture in SA to eat biltong while watching rugby the sales, therefore, can be influenced by political decisions.

The second factor the company has little control over is environmental. For example, when there is a drought, the factory has no control over the situation, but it can influence the company's costs if the price of water is increased. A draught can also influence the price of cattle as there can be less cattle available due to the draught.

The social factor influences the company's market as it is part of the South African culture to eat a lot of meat and biltong snacks are part of this culture. The technology factor has a great influence on big scale biltong producers. When competitors use a new machine that produces biltong in a fraction of the time the company will not be able to compete with price and will in effect lose their market share.

The factory does not have full control regarding the pricing of their products due to the following Micro-environment role-players: The competitors, suppliers and customers. The competitors have control over the pricing of the Factory's products, as the Factory must be able to compete with their competitors' price in order to ensure sales. The suppliers' price is influenced by a variety of factors, such as the meat market price. Therefore, it can't be influenced by the Biltong Factory to some extent. The consumers also have power over the price the company asks, as they can be willing to pay a certain price per kilogram for biltong.

At the internal business environment, the only control that the factory has regarding reducing costs is over the production processes. The remaining factors such as employees, cash flow, capital assets, and structure, will influence the operations and revenue of the business when managed poorly. Thus, for these factors the management is of great importance. Therefore, to increase profitability or competitiveness the only factor that the Biltong Factory has control over to influence their costs is the efficiency and cost of the production processes involved to produce their products.

By understanding the use case's business environment, it can be used to determine in what area of the business environment the Biltong Factory has the power to reduce costs. Through the discussion and illustration above in Figure 3.7, it is clear that the only factor the Biltong Factory has control over to enable them to be more competitive or cut costs is by improving the production processes.

Section 3.3 and 3.4 provides information regarding the use case in order to identify an area that needs improvement to then develop a production management model for this identified area.

3.5. Identify Improvement Area

Section 2.2.1 describes that a company is profitable when the value the company creates exceeds the performing cost of value activities. In order to achieve a higher total profit margin, the value activities can improve their efficiency and reduce cost (Feller, Shunk and Callarman, 2006). The value stream activity that this study will focus on will be identified based on where improvement will have the greatest impact on the whole value stream. This section will focus on identifying an area for improvement in the VSM, to have the greatest improvement impact on the Biltong Factory's competitiveness through increased efficiency.

3.5.1. Quality versus Price

The Biltong Factory provides products to big retail stores, the factory can be classified as price setters, as the factory does not have to accept prices that are set by other small providers (Gowthorpe, 2005). Although the Biltong Factory is a price setter, their products' prices are influenced by supply and demand. Their product price must still be competitive to prevent getting priced out of the market by big competitors.

According to Porter *et al*. (1985), in order for a company to gain competitive advantage they must either perform value activities in a way that would lead to differentiation and a premium price, or perform activities at a lower costs. Section 2.6.1, states that the new method to determine what the profit of a company will be is to first determine the price the customer is willing to pay and then to subtract the cost (Tapping, Luyster and Shuker, 2002). Thus, the price is fixed and the only way to increase profitability or competitive structure is to reduce costs of the value activities.

As stated in Section 2.2.2, 'In some industries the quality or non-price factors are on average as important as, or more important than price. In most markets there are essentially more dimensions regarding quality on which competition can differentiate a product and/or service than price dimensions. Thus, in some industries it is more likely that the quality factor will be the decisive factor that influences the customer's choice (Buxton, Chapman and Temple, 1998).' The reason behind the Biltong Factory's brand loyalty is their superior quality products. The aspect of quality is therefore of greater significance than the aspect of price in this use case.

The product's quality is an important aspect of what the customer views as value. Based on Section 2.7.1, the 'wow' factor of value is achieved when providing a product/service that would not only satisfy customers but "make your customers successful" (Feller, Shunk and Callarman, 2006). This is specifically important in the Biltong Factory's case, where the customer is often not the end consumer of the product, but rather a reseller. The 'wow factor' of value is provided to the biltong resellers by supplying them with superior quality products, as this creates high end-customer satisfaction, which in turn ensures repeat business for the resellers.

Through the VSM discussion previously, the processes that have the greatest influence on the product quality are the cutting and drying processes. Although the drying process is dependent on the type of product being dried, the weather conditions and the customer's requirements, the process can only be monitored in order to get the correct dried percentage.

The drying process is the most crucial process regarding creating value for the company and customer. Therefore, the monitoring of the process is of utmost importance. However, when the cutting or meat preparation process is done poorly the products quality will not be consistent. For this reason, the drying will also not be consistent even when monitored correctly.

For example, a poor-quality batch will have cuts that were cut too thin or too thick. The batch is dried for the same amount of time, but some of the pieces will be excessively dried and some still too wet. Therefore, the product quality will be poor. This could lead to the customer being unsatisfied and the biltong could possibly be returned. Based on this discussion, it can be stated that even when the drying is monitored to precision, the cutting or meat preparation quality of the wet product can still influence the end product's quality.

3.5.2. Identify Value-Added Process

In order to identify an area for improvement it is also important to understand that the 'Wet Factory' must produce more than double the weight than the amount of end products being sold. The wet products loses a minimum of 55% of its original weight. To cover the 1.6-2 tonnes of products shipped per day, as depicted on the VSM, the 'Wet Factory' must produce between 3.5-4.5 tonnes of wet products per day. Therefore, there is great pressure on the 'Wet Factory' to produce enough wet products to satisfy customers' orders. For this reason, it can be stated that the 'Dry Factory' is dependent on the 'Wet Factory'.

One of the important tenets of Lean, as stated in Section 2.6, is the seamless movement through value-creating activities (McManus and Millard, 2002). One of the design questions for a future state map discussed in Table 2.5 Section 2.8.2.1 is: What single point within the production chain can be used to schedule production? The pacemaker process to focus on to improve the production flow for this use case is the cutting or meat preparation process. This process is the starting point for all the various products, as seen in the VSM. Thus, all the other value-added activities can only start after the cutting process or meat preparation process is complete.

The financial statements of the 'Wet Factory' were also analysed to determine the aspects with the highest cost. By determining the average cost over 3 months, it is clear that the material cost is the highest expense and second to that is the labour cost. Therefore, the production processes used to process the raw material and the labour associated with these processes require better management; to have an improvement impact. In Section 4.2 a discussion follows on how these two factors were considered to be better managed through the production management model.

Based on the discussion in Chapter 3 and Section 3.5 thus far, the area for implementing improvement was identified as the use case's 'Wet Factory' and more specifically the cutting or meat preparation process.

3.5.3. Product Family

Section 2.8.2.1 states that product-quantity analysis is one of the methods that can be employed to determine which value stream(s) to target to implement improvement. This analysis is done by determining whether some part numbers have volumes high enough to target as the value stream (Tapping, Luyster and Shuker, 2002).

A product-quantity analysis was done by determining the percentage sales volumes of the Biltong Factory's products in order to determine what products to focus on. The percentage sales volumes in Table 3.3 were based on data provided over a period of three months.

Table 3.3: Percentage sale volumes for biltong product groups.

Product Group Name	Sales %	Beef Input required
Silversides	12.48%	Silverside Flats/ Silverside A grade
Silverside Eyes	0.01%	Silverside A grade
Silverside Triangle	0.31%	Silverside Flats/ Silverside A grade
Sliced Biltong (SB's)	25.44%	Silverside Flats/ Silverside A grade/
Baby Biltong	0.90%	Topside
Chips	0.49%	Topside
Shredder/Shaved Biltong	0.32%	Topside
Salad Cuts	0.26%	Topside
Snapsticks	21.27%	Topside/ Flank Steak
Topside Silverside Lean	1.84%	Topside
Beef Nuggets	6.67%	Trim and Fat
Biltong Wheels	0.21%	Trim and Fat
Beef Droëwors	19.16%	Trim and Fat
Chicken	0.79%	
Game (Biltong/Droëwors)	1.45%	
Kudu (Biltong/Droëwors)	3.35%	
Ostrich (Biltong/Droëwors)	3.23%	
Springbok (Biltong/Droëwors)	1.79%	

More information on the products and different cuts are provided in Appendix A. The products with the highest sales' volumes are highlighted in grey in Table 3.3. It clearly illustrates that the highlighted four products are responsible for almost 80% of sales. It was observed that the higher selling products (larger than 10%) all require Silverside Flats, Silverside A grade, Topside or Flank steak cuts.

The beef *droëwors*, with an 19.16% sales volume, consists of trim and fat that originate from these steak cuts, as they go through the different cutting processes. For this reasoning, it was decided to focus on the meat processes that these different meat cuts must go through in order to produce the different products with the largest sales percentage volumes.

In Section 2.8.2.2 the first step of the improved VSM procedure is to select a product family. A product family is defined as 'a group of products that pass through similar steps in the process and over common equipment in the downstream processes' (Braglia, Carmignani and Zammori, 2011). To determine whether these products identified above are part of a product family, an understanding of the production or process routings were undertaken.

Through observations, the layout of the 'Wet Factory' (see Appendix B) and the production routing maps of the different meat cuts (see Appendix C) was developed in Microsoft Visio®. The process routing maps of the products clearly illustrate that the products go through similar steps and use similar equipment. Therefore, these groups of products were classified as the product family to target for implementing improvement. For this reason, the proposed improvement model will focus on the most popular products as they form part of a product family and by improving the management of these processes it will have a great impact on the efficiency of the factory.

Section 3.5 identified the area for improvement, for which the production management model will be developed for, as the 'Wet Factory's' cutting processes for the specific product family cuts namely Silverside Flats, Silverside A grade, Topside or Flank steak.

3.6. Chapter 3 Summary

This chapter first looked at the biltong Value Chain to identify the phase of the chain where the use case fits in. Then the Biltong Factory's process maps for the wet and dry factory were mapped in order to understand the factory's processes to develop the VSM for the use case. A business use case analysis followed in order to understand the type of production, price policies and business environment of the Biltong Factory. All this information was then used to identify an improvement area by looking at the quality versus price aspect of the company, by identifying a value-added process and determining a product family to be targeted for improvement.

Hence, the following literature from Chapter 2 was applied to the Biltong Factory: the biltong Value Chain, VSM, production classification, value proposition (quality versus price), and product quantity analysis. This literature concepts were applied in order to investigate the use case in greater depth and to ultimately identify an area to develop the production management model for. The production routing maps in Appendix C were also used to understand the processes, to collect the time study experiments data, which are further discussed in Chapter 4.

The area that will be the focus point of the subsequent research was identified as the 'Wet Factory's' cutting processes for the Silverside Flats, Silverside A grade, Topside, and Flank steak cuts product family.

Chapter 4

Production Management Model Development

This chapter[3] is concerned with the information required for the production management model development. This section of the study will focus on the 'Wet Factory' as the point where the most significant impact of production improvement can be achieved. This improvement will take place in the cutting or meat preparation processes of the product family.

The chapter discusses the requirements for the type of data and experimental setup used to collect the performance measurement data. To determine the type of data to be collected the previous literature and on an in-depth understanding of the use case's production, as discussed in Chapter 3, were used.

The methodology used to determine the production management model function is discussed in this chapter. The function of the model is determined to support the model development phase, which is also discussed in this chapter.

Based on the methodology discussion in Chapter 1 and more specifically Figure 1.1, this chapter also forms part of the continuous process that was followed for the generic approach development.

4.1. Data Collection

To develop a production management model for the Biltong Factory and to improve the use case's management and control, performance measurement data is required. The data was collected from the factory through time study experiments for each process part of the product family.

To determine how many time study replications were required to calculate an average output rate per process, a Single Sample t-Test sample size calculation was done in Statistica at the Stellenbosch University Centre for Statistical Consultation. The theory and calculations used to determine how many time studies are required, are discussed next.

[3] A large portion of the contents of this chapter was published in the 29th South African Journal for Industrial Engineering (SAJIE) in 2018. Attached in Appendix G.

4.1.1. Cycle Time

One of the cornerstones of effective manufacturing strategies, as discussed in Section 2.2.4, is the tracking and monitoring of performance regularly (Hill, 2000). A primary feature of performance measurement is the measurement of cycle time (Maskell, 1991).

The cycle time can be used as an indicator to measure the efficiency of a production process (Rother and Shook, 2003). Therefore, the cycle time is determined by measuring the time for each process (see Appendix C), which forms part of the group of products identified in Chapter 3. Based on Section 2.9.3, the cycle time is only measured for the highlighted red sections depicted in Figure 4.1

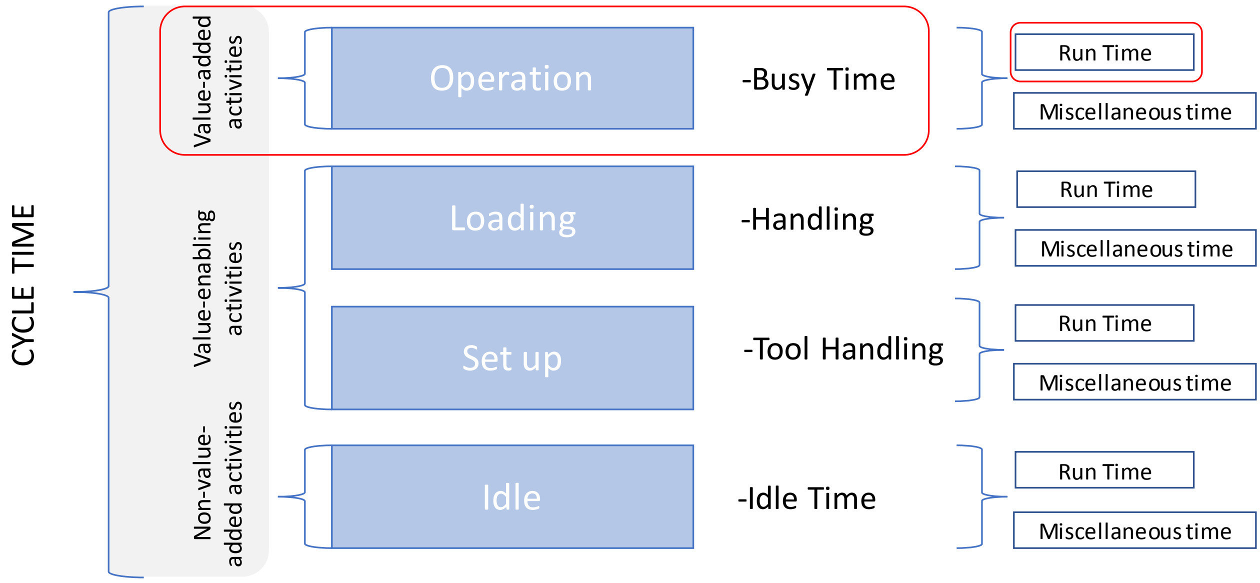


Figure 4.1: The cycle time components measured for use case.

The cycle time was only measured for the operation run time or busy time. Thus, the time during which a unit is worked on, for each value-added activity process.

4.1.2. Sample Size Calculation

Power analysis is an important aspect of experimental design. The analysis is used to determine the sample size required to detect an effect of a given size, with a given degree of confidence. On the other hand, it can be used to determine the probability of detecting an effect of a given size, under certain sample size constraints. When the probability is too low the experiments need to be altered or abandoned (DataCamp, 2016).

The following four quantities have an intimate relationship, and given any three, the fourth can be determined (DataCamp, 2016):

1) Sample size
2) Effect size
3) Significance level = P (Type I error) = probability of finding an effect that is not there.
4) Power = 1 – P (Type II error) = probability of finding an effect that is there.

The following theory was used to provide an understanding of the effect size impact.

To test the hypothesis that four means are the same, then:

$H_o: \mu_1 = \mu_2 = \mu_3 = \mu_4$ versus $H_1: \mu_i \neq \mu_j$

The effect size can be defined as:

$$\boldsymbol{\delta} = \frac{\boldsymbol{max}(\mu_i) - \mathbf{min}(\mu_i)}{\sigma} \quad \textbf{4.1}$$

Where $\sigma = standard\ deviation$

In terms of the effect size, the hypothesis can be restated as:

$H_o: \delta = 0$ versus $H_1: \delta > 0$

An effect size of:

$\delta = 0.25$ is regarded as small

$= 0.75$ is regarded as medium

$= 1.25$ is regarded as large

The power of the test is defined as:

$Power = Probability\ (Reject\ H_o\ for\ given\ \delta)$

Figure 4.2 depicts the information discussed above.

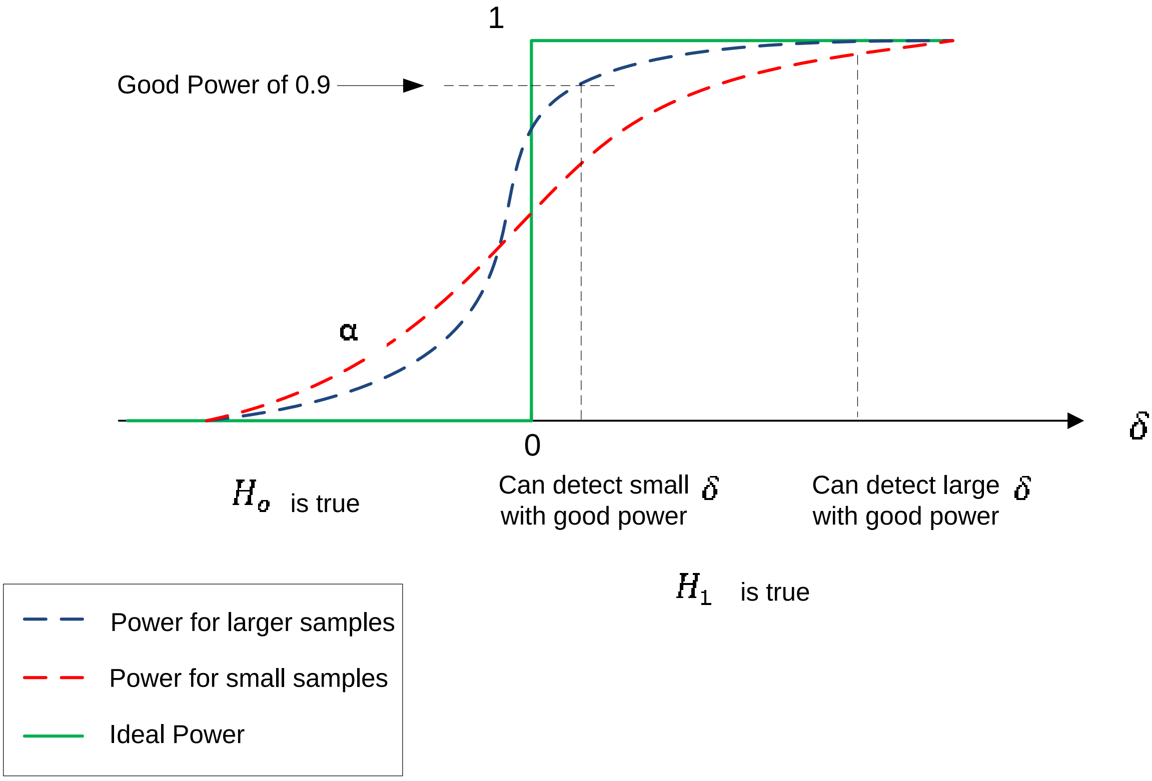
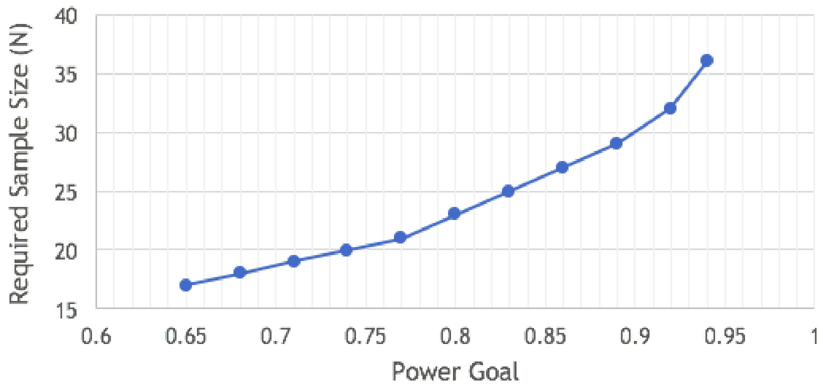


Figure 4.2: Power analysis.

To calculate the required number of time study replications required to estimate an average time per process, the following calculations were done in Statistica. Figure 4.3 illustrates the Single Sample t-Test sample size calculation results.



Description	Value
Null hypothesised mean (Mu0)	0.00
True population mean (Mu)	6.20
Population S.D. (Sigma)	10.00
Standardised effect (ES)	0.62
Type I error rate (Alpha)	0.05
Power goal	0.90
Actual power for required N	0.9068
Required sample size	30.00

Figure 4.3: 1 Sample t-Test sample size calculation (Left) and Results summarised for the sample size calculation (Right).

From the illustration in Figure 4.3, it can be observed that to detect a standardised effect of δ = 0.62 with 90% power and significance level of 5%, a sample size of η = 30 replications of each meat process is required. The effect size of δ = 0.62 is sufficient as the effect size is between the small (0.25) and medium (0.75) effect size.

4.1.3. Time Study Experiment Steps

Figure 4.4 illustrates the experimental steps that were followed when time studies, for the processes mapped in the production routing maps in Appendix C, were conducted at the factory. Some processes from the production routing maps were not measured as these processes were only used in rare cases. Therefore, some of the mapped processes are not part of regular production. The experiments were done in batches of 5 and were repeated until 30 experiment replications were completed.

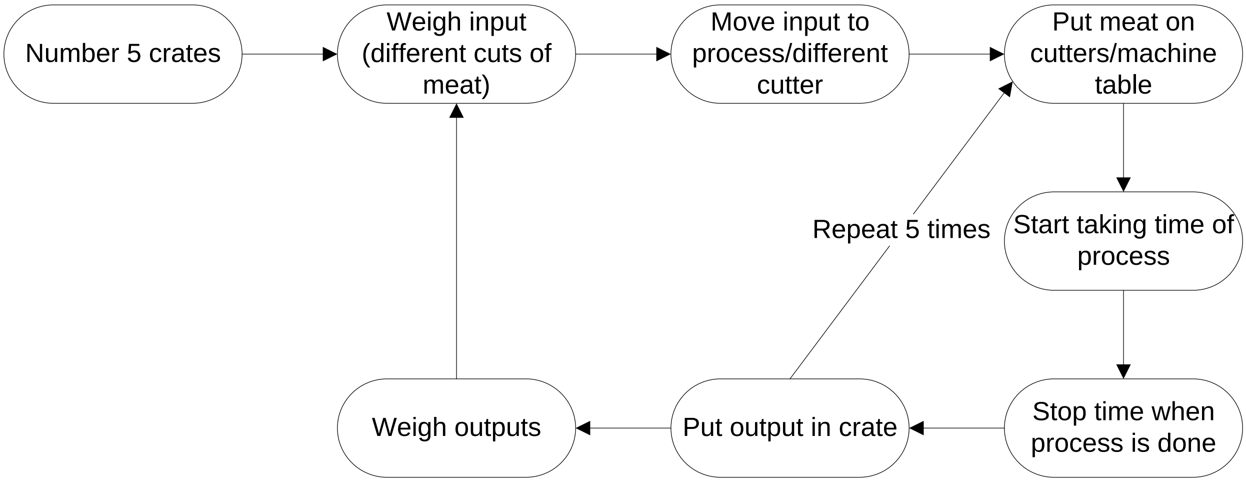


Figure 4.4: Process followed for time study experiment in Biltong Factory.

The first step was to number five crates, to keep all the input and outputs separate while doing five experiments at a time. The different cuts or inputs in each crate were first weighed and documented on the sheets that were provided. After each crate's input meat was weighed, the crates were moved to the process that was being timed.

The meat was then placed on the cutter's table or when machines were used it was placed on the table where the machine was positioned. When the cutter or person managing the cutting machine started with the process the time it takes to complete the process was taken and documented on the sheets that were provided (see Appendix D). After the time was recorded for each input, the outputs of meat were then put in their specific crate. After the process of taking time studies was done for five separate inputs or crates the outputs were then weighed.

When the time study experiment for five inputs were completed, the next five time studies followed. The same experimental steps were followed with new input meat at the same process. This was then repeated six times to get thirty-time studies for the specific process. After the thirty time study experiments were completed, the next process's time studies were conducted using the same procedure.

The time was only taken for the process's run time as discussed in Section 4.1.1. Therefore, the time that it takes to clean stations, sharpen knifes and transport time to move crates to the different processes were not considered. When there were multiple workers working at the same process, a different worker was timed every five-time studies.

To keep the variables constant during the experiments the following was done:

- The same scale was used;
- Only one piece of input meat was used for each experiment (Silverside Flat, Silverside A grade, Topside, Flank steak);
- The inputs and outputs were kept separate for each experiment and
- Data sheets were used to document the experiment data (Appendix D);

In the subsequent section, the production management model function is discussed, which will be used during the development phase of the production management model itself.

4.2. Production Management Model Function

According to Section 2.2.4, an enterprise's success is measured in terms of three economic global goals namely, high quality, short lead times as well as low costs (Mayer and Nusswald, 2001). The production management model must help the factory to strengthen their competitiveness by improving the quality, lead times, as well as costs. The model function is first determined in order to start the development process with a clear vision.

4.2.1. Line Flow

By determining the cycle time of the different processes, the line flow can be improved with line balancing and in effect the manufacturing time will be improved. The cycle time information can be used to calculate the process times and the number of workers required at the specific operations. As a result, this information can be used to determine the most efficient sequence of processes to complete an order in the shortest time by considering the available resources.

The production management model will adapt according to the available resources, thus allowing for flexible process balancing. According to Section 2.2 the improvement on time allows for a higher production rate, which in affect also improves efficiency and cost effectiveness (Squire et al., 2006; Größler and Grübner, 2014; Lapré and Scudder, 2004; Hill and Hill, 2009). By improving the manufacturing time and allowing for a higher production rate by using the production management model, efficiency and cost effectiveness can improve.

One of the key concepts of Lean, according to Section 2.6.1, is the cost reduction principle. The production management model further focusses on the cost reduction principle, as one of the aspects to improve the Biltong Factory's competitive structure.

4.2.2. Cost Estimation

The cost estimation method used in this study is Activity Based Costing discussed in Section 3.1.1, as this method assumes activities drive costs (Steward, Wyskida and Johannes, 1995). One of the applications of ABC are to assign cost and time values to activities (Ray and Gupta, 1992). By considering the time experiment data and the manufacturing labour cost, the cost to produce a certain quantity of raw product can be determined.

The basic principle of ABC is that units should tolerate the cost associated with the activity they cause (Gowthorpe, 2005). Therefore, the cost estimation of manufacturing a product can be used by the Factory to determine whether the cost unit bears the cost associated with the activity.

The cost estimation information can also be used by the Biltong Factory to determine whether the profit margins on products are too low, as the cost to produce a certain raw product is determined or known. The different process costs can also be used to determine whether certain processes should not be used at all and alternative processes should be considered.

The production management model will be used to determine the actual cost of manufacturing the raw meat product by considering the labour cost of the 'Wet Factory's' workers. The labour cost to transform the input to a specific output can be estimated with the experimental data.

The following equations were developed to determine the cost of manufacturing the raw meat product for the use case in this study. These equations were developed based on the manufacturing cost equations discussed in Section 2.3.4, and more specifically the following equations: average production time, average production rate and production capacity (Equation 2.9-2.12).

$$\frac{kg}{h}\ [output\ rate\ per\ cutter] \div \frac{Cost}{h}\ [Labour\ cost\ per\ cutter] = \frac{Cost}{kg}\ [\ Labour] \qquad 4.2$$

$$\frac{Cost}{kg}\ [Labour] + \frac{Cost}{kg}\ [Fixed\ meat\ cost] = \frac{Cost}{kg}[actual\ output\ costs] \qquad 4.3$$

$$\frac{Cost}{kg}[actual\ output\ costs] \times Number\ of\ cutters \times \frac{hours}{day} = Capacity\ output\ /day \qquad 4.4$$

4.2.3. Raw Material and Labour Cost

The production management model will calculate the required raw meat input needed in order to produce a certain order output, as well as the time needed to transform the cut of meat. This is achieved through measuring the input and output weight of each cut of meat when conducting the cycle time experiments. Thus, this experimental data is then used to determine the orders needed to meet demand in a cost-efficient manner. This information can be used to reduce direct labour costs and manufacturing costs. Hence, the production management model can be used to monitor the direct cost.

As discussed in Section 3.5.2 the two aspects from the financial statements with the highest cost, namely material cost and labour cost, will be better managed as described in this section. The material cost will be more accurately managed by determining the input required and the process sequencing to cover an order as discussed above. Secondly, the labour cost can be associated with the manufacturing of the different products to estimate the actual manufacturing cost to manufacture the wet products.

From this section it can be said that the function of the production management model should include the following to have an improvement impact on the Factory's efficiency and in effect their competitiveness. The model function should determine the input raw meat required, the most efficient sequencing of processes dependent on the received order, the time required, and the manufacturing cost per order.

4.2.4. Production Management Model Function Roadmap

Figure 4.5 depicts the developed roadmap to illustrate the methodology that was followed in order to determine the production management model function and the area that needs to be focused on in the use case for implementing improvement. The roadmap also indicates the phase that will follow namely the model development phase.

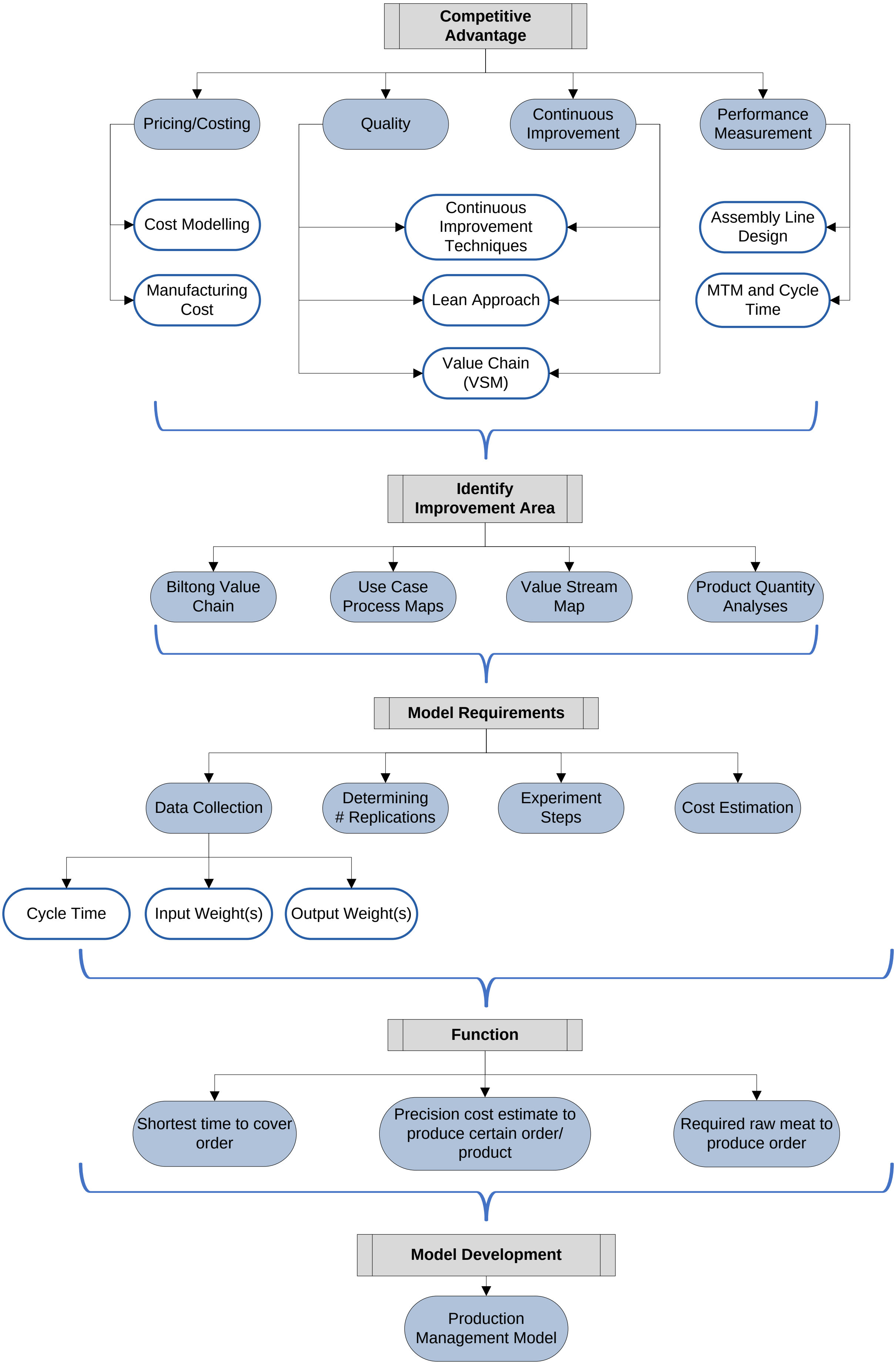


Figure 4.5: Roadmap followed for determining the production management model function.

The first step of the methodology roadmap is to conduct research on competitive advantage concepts and tools. This information is then used to analyse the factory and to determine an improvement area to develop the production management model for. After an area for improvement was identified, the data required to develop the production management model specifically for the Biltong Factory, was determined.

Once the data required for the production management model was determined, the model function was then established. By determining the model function first, the production management model can be developed with a clear vision of the purpose the model must achieve.

The production management model development, which is the next phase of the roadmap depicter Figure 4.5, is discussed in the subsequent sections. The developed production management model, which is the final step of the roadmap in Figure 4.5, is discussed in Chapter 5.

4.3. Production Management Model Development

This section consists of the data formulation of the collected experimental data that was required in order to develop the production management model to achieve the function as discussed in the previous section. Thus, this section discusses the analysis and model development formulation that was done after the data was collected through time study experiments.

4.3.1. Experimental Data Analysis

The raw data retrieved from time-study experiments is depicted in Appendix E. In total, 30 replications were done for each process' time, input weight and output weight. The measured experiment data for the production time, input, and output weight can differ from real-time data when considering the following:

- The Hawthorne effect, or observer effect, refers to how individuals change or modify their behaviour as a response to being aware that they are monitored or being closely observed (Davis and Feldman, 2013). Therefore, the measured time per process can be affected.
- The required input weight and the measured output process weight can differ from real-time data. The weights differ, because all cattle are grown naturally, thus, the meat characteristics are not exactly the same.
- The measured process time can differ from real time-data, as the efficiency of the workers can change during the day as they may get tired, thus, influencing the processing time.

- The processing time can also be influenced by the skill or experience of the worker. For example, when a new worker works on a process the processing time will be longer compared to the processing time of a more skilled or experienced worker.
- The processes are done by people. Thus, by considering the human factor, the throughput regarding the time and meat output weight, is not necessarily consistent.

To compensate for the above reasons, it was decided to determine the standard deviation of the collected data set to provide a range of data values to be used for the production management model. After the data was collected any obvious outliers outside the third standard deviation were removed. The outliers consist of around 5% of the total data set, therefore indicating that the collected data were reliable. The outliers in the data set could be due to the effect of any of the above listed reasons.

4.3.1.1. Model Equations

The average and standard deviation for each process' time as well as input and output weight were calculated. The percentage output from the input for each process was used to calculate the input required and its associated output for different orders. For each input cut and process there are different outputs as depicted in the table below.

Table 4.1: Input cut and process associated outputs.

Cut	Process	Input	Output
Topside	Cut up triangle	Topside triangle	Lean SB's Trim
Silverside (SS) A grade	Cut up triangle	SS A grade triangle	Triangle SS SB's Fat Lean SB's Trim

The equations discussed below form part of the basis for the development of the production management model.

The following equation was developed to calculate the input weight required of a specific cut (Topside, Silverside Flat, Silverside A grade) and to calculate the output weight of the different outputs when an order is covered.

$$\textit{Input weight required} = \frac{\textit{Order quantity}}{\textit{Sum Multiplication of process output \% to produce order}} \qquad \textbf{4.5}$$

The sum of the output percentages of each process that produce the order, are multiplied by the input percentages from the input total that the process is dependent on.

To calculate the time duration of a specific process the following equation was used for each process:

$$\frac{\boldsymbol{Input\ weight\ required} \times \%\ \boldsymbol{Output\ required\ for\ process}}{\boldsymbol{Input\ weight\ measured\ for\ process}} \times \boldsymbol{Time\ measured\ for\ process} \qquad \textbf{4.6}$$

The following examples will show how the above equations work with practical scenarios.

Example for input required equation: Order of Topside Silverside made using Silverside Flat cut as input and process 1-4. With the outputs of process (proc) 2 and 4 contributing to produce the order weight, process 2 is dependent on process 1 and process 4 dependent on process 3, as depicted in Figure 4.6.

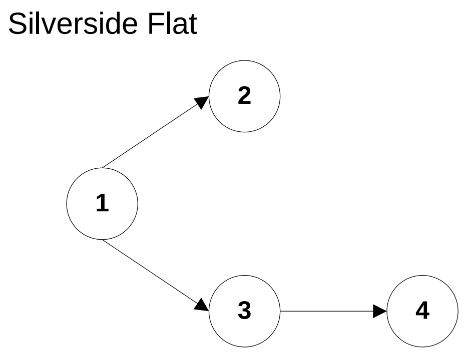


Figure 4.6: Silverside Flat process.

Equation for Topside required for an order of Topside Silverside based on the example:

$$\boldsymbol{Topside\ weight\ required} = \frac{\boldsymbol{Topside\ Silverside\ order\ weight}}{\begin{matrix}\boldsymbol{Topside\ Silverside}\ \%\ \boldsymbol{from\ proc\ 4} \times \\ \%\ \boldsymbol{Output\ required\ for\ proc\ 4\ from\ proc\ 3} + \\ \boldsymbol{Topside\ Silverside}\ \%\ \boldsymbol{from\ proc\ 2} \times \\ \%\ \boldsymbol{Output\ required\ for\ proc\ 2\ from\ proc\ 1}\end{matrix}} \qquad \textbf{4.7}$$

One of the outputs to cover an order of Topside Silverside is also Sliced Biltong Lean (SB's Lean). To calculate the weight of SB's Lean output from processes 1-4, as stated in the above example, the following equation is used: With proc 2 and 4 producing SB's Lean, proc 2 is dependent on 1, proc 4 dependent on 3 and proc 3 dependent on proc 1.

$$\begin{aligned}\boldsymbol{SB's\ Lean\ output} = \boldsymbol{Topside\ weight\ required} \times [&\boldsymbol{SBs\ Lean}\ \%\ \boldsymbol{from\ proc\ 2} \times \\ &\%\ \boldsymbol{Output\ required\ for\ proc\ 2\ from\ proc\ 1} + \\ &\boldsymbol{SBs\ Lean}\ \%\ \boldsymbol{from\ proc\ 4} \times \\ &\%\ \boldsymbol{Output\ required\ for\ proc\ 4\ from\ proc\ 3} \times \\ &\%\ \boldsymbol{Output\ required\ for\ proc\ 3\ from\ proc\ 1}]\end{aligned} \qquad \textbf{4.8}$$

The time duration taken by proc 2 to produce order of Topside Silverside as stated in example are calculated as follow.

$$\frac{\textit{Topside weight required} \times \%\ \textit{Output required for proc 2 from proc 1}}{\textit{Input weight measured of proc 2}} \times \textit{Time measured proc 2} \qquad 4.9$$

The formulas discussed in this section are used as the basis for the rest of the production management model development as further discussed in the next section.

4.3.2. Model Formulation

The next sub-section will discuss how the following was determined: The number of workers to work on each process, the sequencing of processes and the overall processing time. To explain the calculation methods used an actual example will be used. The example uses a specific scenario for the Silverside Flat cut. It is important to state that the calculations differed depending on the different cuts and various process. The example shows the basic principle for the developed equations.

4.3.2.1. Scenarios and Number of Workers

To calculate the number of workers on a certain process, the line balancing technique was used as the time duration per process is known. When calculating the number of workers per process, it is vital to note that each process requires a specific skill and the available workers each day vary due to different reasons like illness, no transport, etc. Therefore, the method used adapts the results according to the order and available workers.

The example will use the following information:

- Order required input: 300kg Silverside (SS) Flat
- Processes used: Process 1-4
- Available cutters for process 1, 2 and 4: 8
- Available workers at slicer for process 3: 1
- Figure 4.6 shows that processes 2 and 3 are dependent on process 1, process 4 is dependent on process 3.

Table 4.2: Process description and required worker.

Process	Description	Worker
1	Clean SS Flat	Cutter
2	Cut up triangle	Cutter
3	Big SS sliced at slicer	Work at slicer
4	Cutter clean SS slices	Cutter

From Table 4.2 it can be seen that the same workers work on process 1, 2 and 4. The batch trigger is seen as the process that the meat needs to travel to in order to be worked on. In this example the batch trigger process is process 3, the trigger is to send a full crate of 60 kg to the slicer table until the order is covered. As process 3 is dependent on process 1 the input required for process 1 in order to send a batch of 60 kg to process 3 is 98.87 kg.

Four different scenarios were used to calculate the number of workers, total processing time and cost. The following illustrations show the four different scenarios:

Scenario 1: All the same workers work in parallel on the different processes

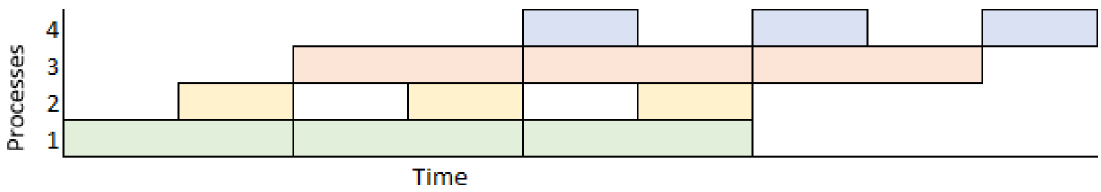


Figure 4.7: Illustration of parallel scenario.

The illustration above shows that although the processes are dependent on each other the batches are worked on in parallel. The workers' division will typically be as it is depicted in Table 4.3:

Table 4.3: Typical worker division for scenario 1.

Process	Time	Actual workers	Time with workers
1	23 min 35 sec	5	4 min 43 sec
2	2 min 48 sec	1	2 min 48 sec
3	4 min 42 sec	1	4 min 42 sec
4	6 min 54 sec	2	3 min 27 sec

Scenario 2: All the workers work on process 1 for 3 batches, as all the processes are dependent on process 1, then they work on process 2 and 4 in parallel.

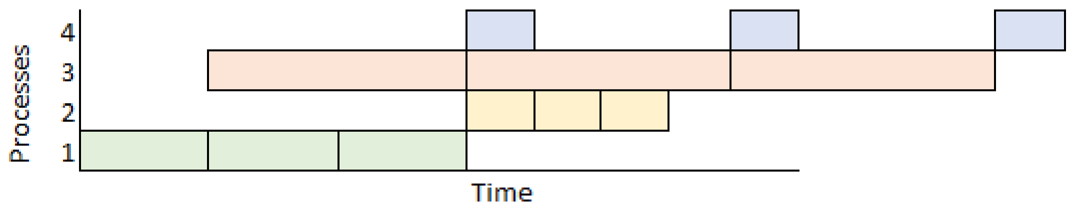


Figure 4.8: Illustration of scenario 2.

From Figure 4.8 it can be seen that the batch process time for process 1, 2 and 4 is shorter than in scenario 1 in Figure 4.7. The workers' division will typically look as follows:

Table 4.4: Typical worker division for scenario 2.

Process	Time	Actual workers	Time with workers
1	23 min 35 sec	8	2 min 57 sec
2	2 min 48 sec	2	1 min 24 sec
3	4 min 42 sec	1	4 min 42 sec
4	6 min 54 sec	6	1 min 9 sec

Scenario 3: All the workers work on process 1 for 3 batches, then they work on process 2 for 3 batches and then on process 4 for 3 batches.

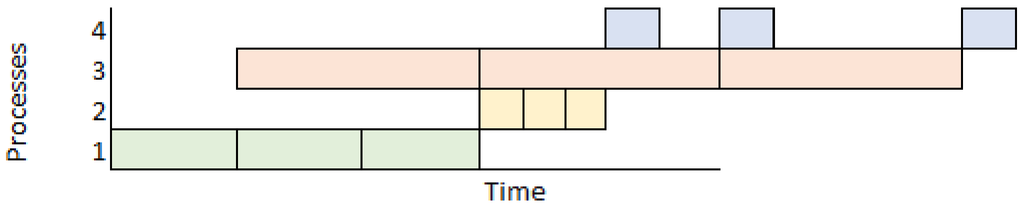


Figure 4.9: Illustration of scenario 3.

From Figure 4.9 it can be seen that the batch process time for process 2 and 4 is shorter and the lead time between the batches of process 4 is also smaller than in scenario 2, in Figure 4.8. The workers' division will typically look as follows:

Table 4.5: Typical worker division for scenario 3.

Process	Time	Actual workers	Time with workers
1	23 min 35 sec	8	2 min 57 sec
2	2 min 48 sec	8	21 sec
3	4 min 42 sec	1	4 min 42 sec
4	6 min 54 sec	8	52 sec

Scenario 4: See process 1 and 2 as the same process as process 2's time is short. All the workers work on process 1 for 3 batches, then on process 4 for 3 batches.

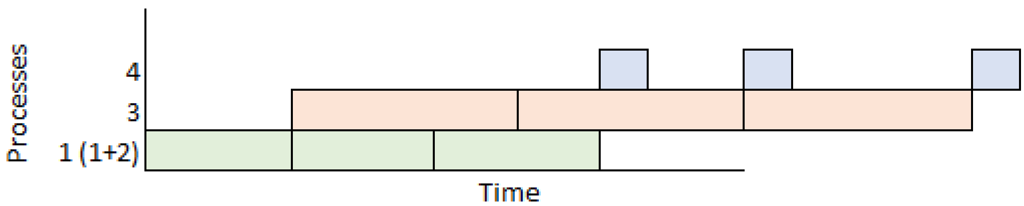


Figure 4.10: Illustration of scenario 4.

From Figure 4.10 it can be seen that the batch process time for process 1 is slightly longer, as process 1 and 2 are seen as one process. The workers' division and process time will typically be as shown in Table 4.6:

Table 4.6: Typical worker division for scenario 4.

Process	Time	Actual workers	Time with workers
1+2	26 min 23 sec	8	3 min 18 sec
3	4 min 42 sec	1	4 min 42 sec
4	6 min 54 sec	8	52 sec

For this scenario the following was considered: The input weight for process 2 is small. To keep the small cuts of meat separate until the batches of process 1 are complete, as in scenario 3, can be extra trouble that takes up time just for a small input weight. Therefore, this scenario considers the two processes as one - to eliminate the extra time and trouble to separate the input meat of process 2.

The following equations for the workers, total processing time and cost will use Scenario 1 for Silverside Flat cut, shown above, as an example. To calculate the number of workers that must work on each process that shares the same workers, Equation 5.10 was used:

$$\boldsymbol{Number\ of\ workers\ on\ proc\ y} = \textbf{Available workers} \times \frac{\textbf{time of proc y}}{\textbf{Sum of time of procs that share workers}} \qquad \textbf{4.10}$$

The table indicates the batch weight, time and number of workers per process that were calculated with the above equation.

Table 4.7: Weight and time per process.

Process	Weight (kg)	Time	Number of workers	Option 1	Actual workers
1	98.87	23 min 35 sec	5.67	6 (round up)	5 (round down)
2	17.27	2 min 48 sec	1	1	1
3	60	4 min 42 sec	1	1	1
4	55.89	6 min 54 sec	1.65	1 (round down)	2 (round up)

The table shows the input batch weight to be 98.87 kg. To cover a customer order of 300 kg ±3 batches are therefore required. For illustrative reasons the number of batches required are taken as 3 batches. From the table it can be seen that the number of workers is not integers. For this reason, these numbers are rounded up and down and the division of workers with the shortest overall time are then chosen for the optimal division of workers between processes. For this illustrative case the optimal division of workers are shown in Table 4.7 as actual workers.

4.3.2.2. Processing Time and Cost

Scenario 1 for Silverside Flat cut is used as an example in this section, to show how the total processing time and cost with the number of workers and process sequencing is determined.

The time and cost calculations only take the time worked on the meat into account and not the time used for goods to travel, cleaning workplaces, etc. (as discussed in Section 4.1.1). By implementing continuous improvement and using the model data as a guideline, the factory layout can be improved in future and the traveling time can become negligible. The total processing time was calculated for scenario 1 as follows:

Table 4.8: Time duration per process for order requiring 300kg Silverside Flat.

Process	Time	Actual workers	New time (time/workers)	Total time per process (Time ×Number of batches)
1	23 min 35 sec	5	4 min 43 sec	14 min 20 sec
2	2 min 48 sec	1	2 min 48 sec	8 min 32 sec
3	4 min 42 sec	1	4 min 42 sec	14 min 18 sec
4	6 min 54 sec	2	3 min 27 sec	10 min 29 sec

Total processing times is calculated with the following steps:

1. Calculate the time of process line 1 and 2;
2. Calculate the time of process line 1, 3 and 4;
3. The maximum time out of the 2 process lines is then the total processing time.

Table 4.9: Total processing time calculation.

Process	Total processing time formula	Time per line	Total processing time (maximum from 2 line)
Line 1 and 2	=Max (p1, p2)×b	14 min 20 sec	22 min 29 sec
Line 1, 3 and 4	=Max (p1, p3, p4) ×b +pi+pj	22 min 29 sec	

Where Max is the maximum time out of the processes, sec; p is the process time, sec; b is the number of required batches in this case 3; i and j is the 2 processes' times that are not the maximum out of the 3 processes. By following the steps above and the formulas in Table 4.9 effectively, the total processing time is calculated as illustrated with blue brackets in Figure 4.11:

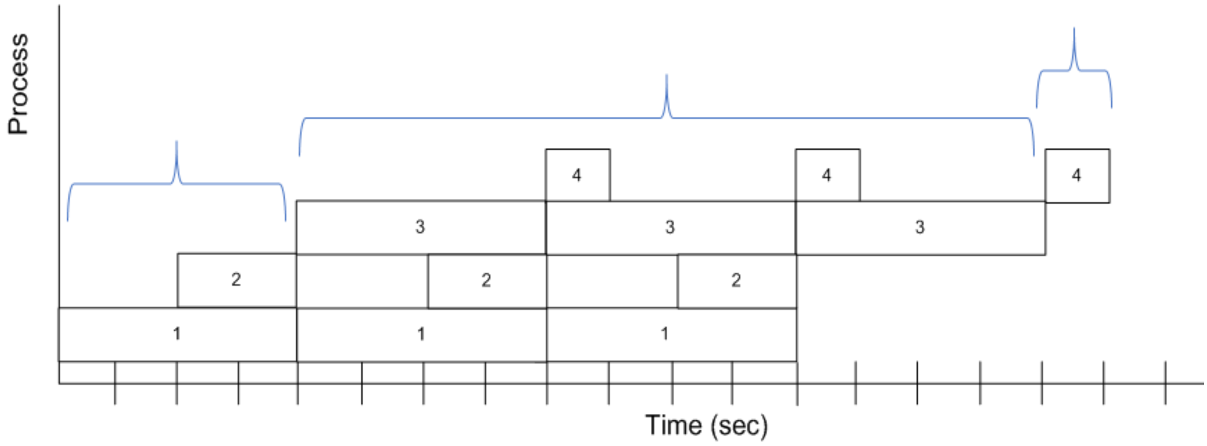


Figure 4.11: Total processing time illustration.

The sum of the time of the blue brackets is the total processing time. To calculate the cost associated to produce the order, the following equation was used:

$$\boldsymbol{Cost = Time\ (seconds) \times \frac{Rate\ per\ hour}{3600} \times Number\ of\ workers} \qquad \textbf{4.11}$$

For the example the cost calculation used the following information:

The rates used as an example:

- Cutters: R30/hr
- Workers at slicer: R20/hr

Time used to calculate cost:

- Process 1, 2 and 4: The same workers work on these processes, therefore the time to complete process 4 was used, as this process is the final process in the line, to calculate the cost.
- Process 3: Requires process 1's output. For this reason, the time to complete process 1 and 3 was used to calculate the cost. As process 3 make use of a different skilled worker and must wait for process 1 before process 3 can start. The total processing time to complete process 4 was not considered to calculate the cost of process 3. The workers at process 3 can do other work after process 3 is complete, thus they do not need to wait for process 4 to be completed.

Table 4.10: Total cost.

Process	Workers	Rate	Line finish	Cost	Total cost for process 1-4
1, 2, 4	Cutters	R30/hr	22 min 29 sec	R 89.96	R 96.31
3	Slicer	R20/hr	19 min 2 sec	R 6.35	

This section discussed how the data was used to determine the processing time and cost and the different scenarios used for these calculations. The calculated information from this section form part of the model formulation. The model, discussed in the next section, uses, these calculations to adapt according to the user input.

4.4. Chapter 4 Summary

Chapter 4 discussed the data collection required to establish accurate performance measurements for the use case's processes. The experimental steps that were followed to determine the cycle time and throughput rate per process were also discussed. The chapter also describes the roadmap that illustrated the methodology that was followed to determine the focus area and function of the production management model to assist with the development phase, which was then discussed.

This chapter concluded with a discussion about the production management model development phase that followed after the required data was collected from the Biltong Factory. The data analysis and equations used to process the data set were used as a basis for the data formulation of the production management model. The different scenarios and the basis of the model formulation equation used in the production management model were then discussed. The subsequent chapter discusses how these goals were achieved through the developed production management model.

Chapter 5

Model Results and Generic Approach

To improve the use case's operations to ultimately increase their competitiveness through increased efficiency, it is suggested that a production management model should be developed. The model will manage the production process namely the cutting or meat preparation process of the 'Wet Factory'. This production management model will also manage the processes in such a way as to assist in reducing waste, as well as increasing throughput or response time.

The developed production management model used the determined cycle time of the different meat processes. Based on the primary and support activities definition in Section 2.7.2. The model focusses on the efficiency of the primary operation activities of the 'Wet Factory', to develop a support activity model or a model that forms part of the infrastructure. Thus, the production management model is a support activity to help improve the primary activities

This chapter discusses the developed production management model's results. The model results discussion forms part of the model development phase of the process, depicted in Figure 1.1, that was followed to refine the generic approach as discussed in Chapter 1. The chapter is concluded with the primary aim of this research, i.e. the developed generic approach. The approach was based on the phases followed to develop an improvement tool for the use case, thus the content of Chapter 3 to Chapter 5. Ultimately, the final generic approach is presented and discussed at the end of Chapter 5.

5.1. Production Management Model

This section will discuss the developed production management model and the information provided by the model results. The production management model was developed by using Excel Visual Basic for Applications (VBA). The VBA model consists of 5 438 lines of code and the buttons used in the VBA model are shown in Appendix F. Figure 5.1 depicts the process of how the production management model works.

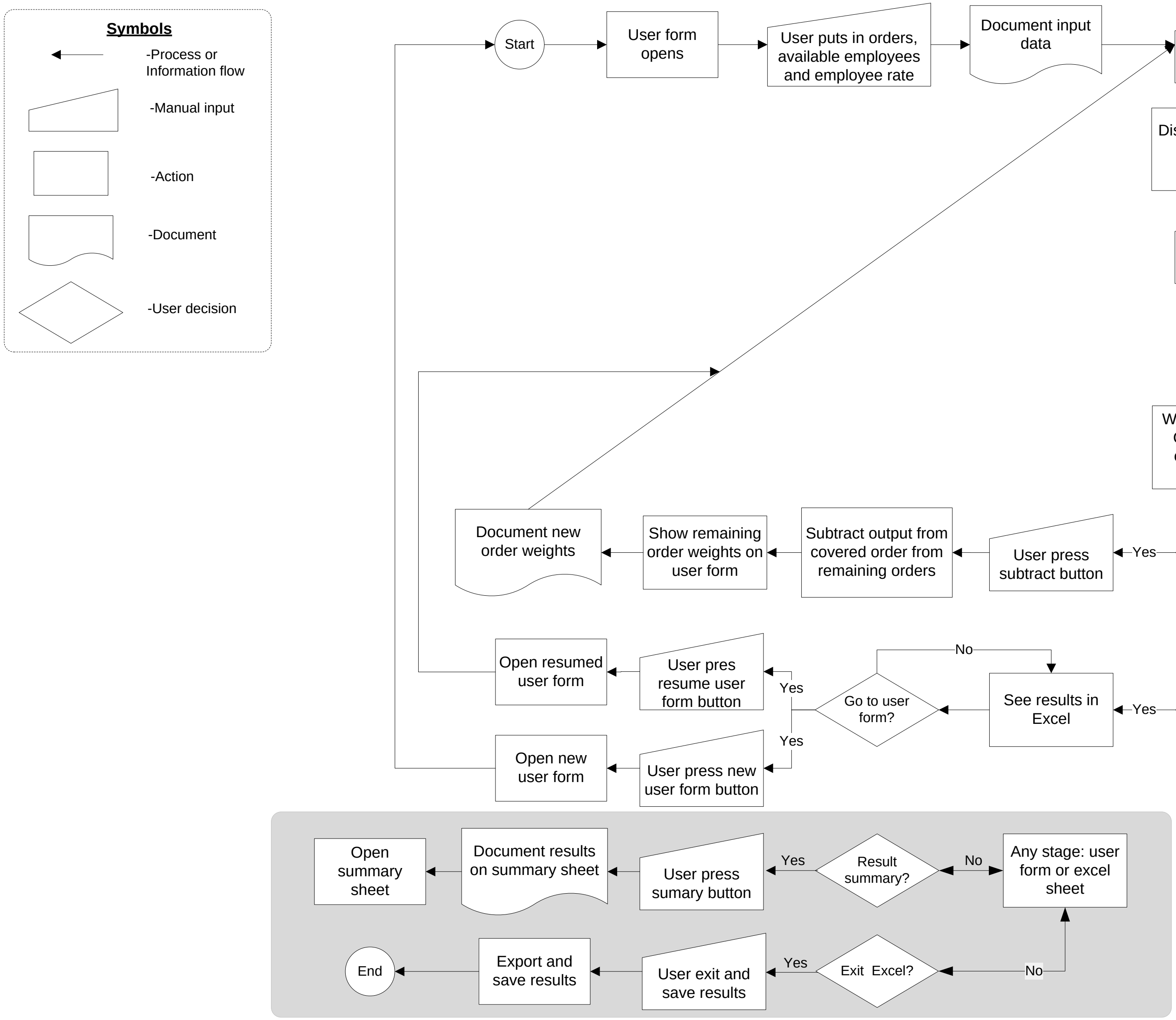


Figure 5.1: Process flow of production management model.

When the user opens the worksheet the user form automatically opens, depicted in Figure 5.2. The user then puts in the order weights for each product (at 1 in Figure 5.2), the employees available for the different skilled processes as well as the employee rate per hour (at 2 in Figure 5.2).

From the list of orders, the user can then select an option that they want to cover first (at 3 in Figure 5.2). The order values are then documented in Excel for further calculations. Figure 5.2 depicts the user form and illustrates in red where the user inserts the orders and employee data, as well as where the user selects the order they want to cover.

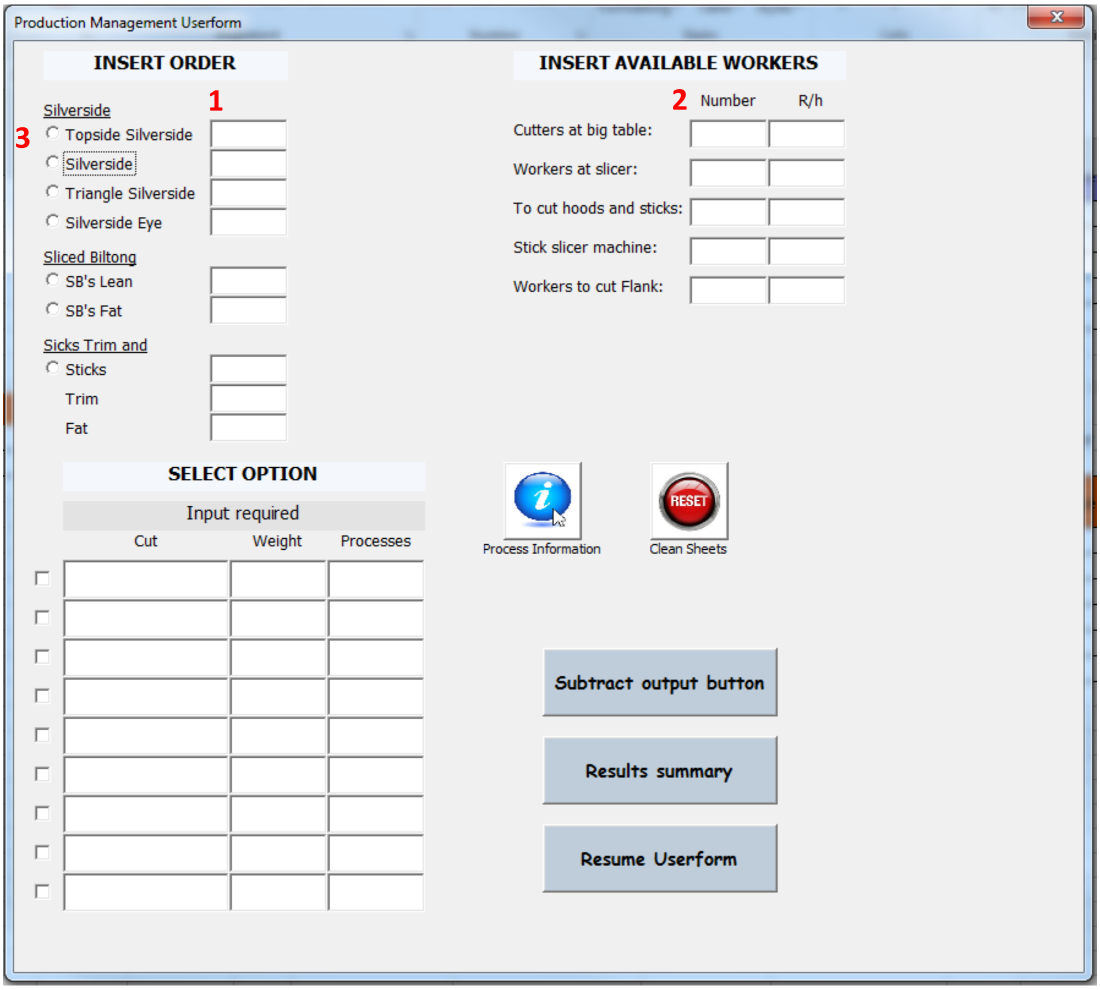


Figure 5.2: User form.

After the order that the user wants to cover has been selected by the user, the selected order's input required is then given as different options on the user form. The information provided includes the different options of input cuts, the input weight in kg and processes required to cover the order. The user can then choose which option he/she wants to use for the order from the list of input required.

These options are provided to the user to choose from for the following reasons: The price for certain cuts can differ on a monthly basis and negotiations with suppliers can influence price. For this reason, the different input cuts and weights required to cover an order are given to the user to choose from.

The available workers with certain skills and the machine availability, due to maintenance or breakage, can also influence the processes that can be used.

For this reason, the different processes used to cover an order are also provided to the user to choose from. Therefore, the input choices are given as options in order for the factory to consider different aspects before selecting a specific input. Figure 5.3 displays the input required list based on an example.

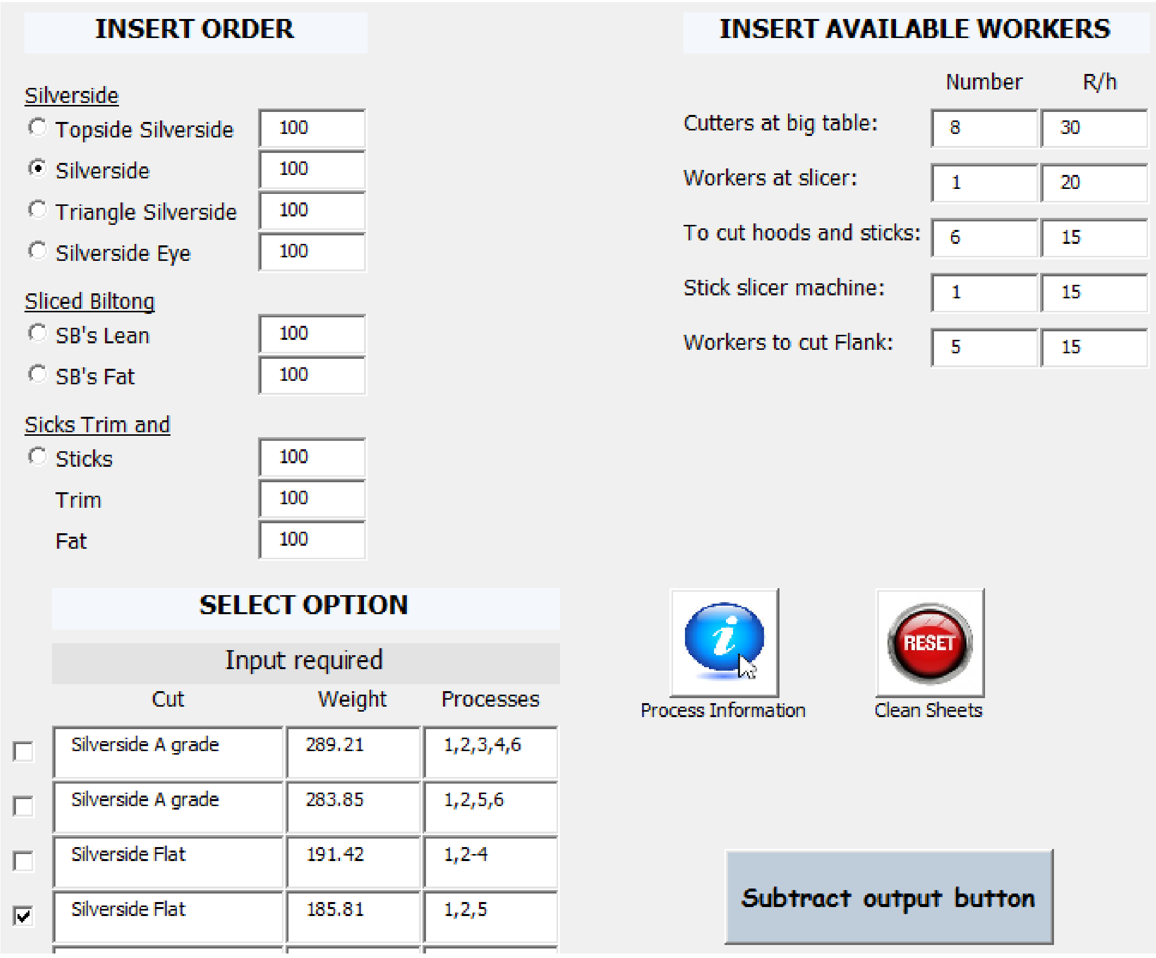


Figure 5.3: Example of user form with input required options.

The input required list indicates that to produce 100 kg of Silverside, 2 different cuts can be used, 4 different process variations can be used and 4 different input weights, based on cut and process variation, can be used. In this case, the user selected option 4 to use Silverside Flat cut and processes 1, 2 and 5 to produce the order. For information on the different processes the user can press the process information button as depicted above on the right-hand side of the input required lists. This button will open the window depicted in Figure 5.4.

Process Information

Cut	Process	Description	Workers
TS SS F SS A	1	Clean meat cut	Cutters at big table
	2	Cut up triangle	Cutters at big table
	3	Big SS sliced at slicer	Workers at slicer
	4	Cutter clean SS slices	Cutters at big table
	5	Cutter cut up Big SS in SS slices	Cutters at big table
SS A	6	Cut up SS eye	Cutters at big table
TS	7	Prep Hoods for sticks	To cut hoods and sticks
	8	Cut hoods in sticks by hand	To cut hoods and sticks
	9	Cut hoods in sticks by stickmachine	Stick slicer machine
	10	Big SS and triangle sliced at slicer	Workers at slicer
	11	Thin TS slices for stix by stickmachine	Stick slicer machine
	12	Cut thin TS slices in sticks by hand	To cut hoods and sticks
Flank	13	Prep Flank for sticks	Workers to cut Flank
	14	Cut Flank steak in sticks by hand	Workers to cut Flank

Figure 5.4: Process information window.

The process information window shows the process description for each process, the processes that are associated with the different meat cuts and the workers that are associated with each process.

The option best suited for the factory chosen by the user in Figure 5.3, is then documented in Excel to do the required calculations for the results. Based on the inserted orders, available workers, chosen input weight, cut, and processes, the results for the outputs, processing time, number of workers to work on each process and cost to produce the order, are then displayed on Excel. Figure 5.5 shows a summary of the results the user will see when he/she exit the user form based on the user's input.

100.00	kg	Silverside	
Input Required:			
185.81	kg	Silverside Flat	Processes: 1,2,5
Outputs:			
100.00	kg	SS	
14.55	kg	Triangle SS	
25.06	kg	SB's Fat	
36.21	kg	Trim	
4.15	kg	Fat	
2.21	kg	Sinew	

Number of Batches:		1.88	Maximum number of batches:	6
Batch trigger: Send 60kg to Process			5	
Option 1:	All the same workers work in parallel on the different processes			
	Total Processing Time:	9 min 17 sec		
	Total Cost:	R 37.14		

Processes	Number of workers	Time (sec)	Time (h min sec)
1	5	531.9449	8 min 52 sec
2	1	316.6402	5 min 17 sec
5	2	557.0587	9 min 17 sec

Figure 5.5: Screenshot of results for input required, outputs and their weights, processing time, number of workers per process, and processing cost.

The results for the outputs and their weight, processing time, number of workers per process and cost are then displayed on Excel as depicted in Figure 5.5. This result can be used in different ways, as discussed under the potential benefits in Section 5.1.1.

Although, Figure 5.5 only depicts the results for option 1 or scenario 1, the results are also shown in the production management model for scenarios 2-4. The maximum number of batches shown in the screenshot is to prevent too much work-in-progress on the floor. The maximum batches are considered in the cases of scenarios 2-4, where the required batches are worked on sequentially or after one another. This is done until the batches are finished before starting with the next process, as discussed earlier. Hence, the maximum batches prevents too much work in progress in the factory before starting with the next process. The limit used to calculate the maximum allowed number of batches, based on practical reasons, is 400 kg.

When an order requires more than the maximum allowed number of batches only scenario 1's results are displayed in Excel. A message box informs the user that the order requires more than the maximum number of batches and if they want to use scenarios 2-4 they must cover smaller batches of orders until the order is fully covered.

The message box also displays the order quantity required to cover the order in smaller batches. The user can then cover the order in smaller batches on the user form and copy or export the Excel sheet's results. Figure 5.6 depicts the 2 message boxes.

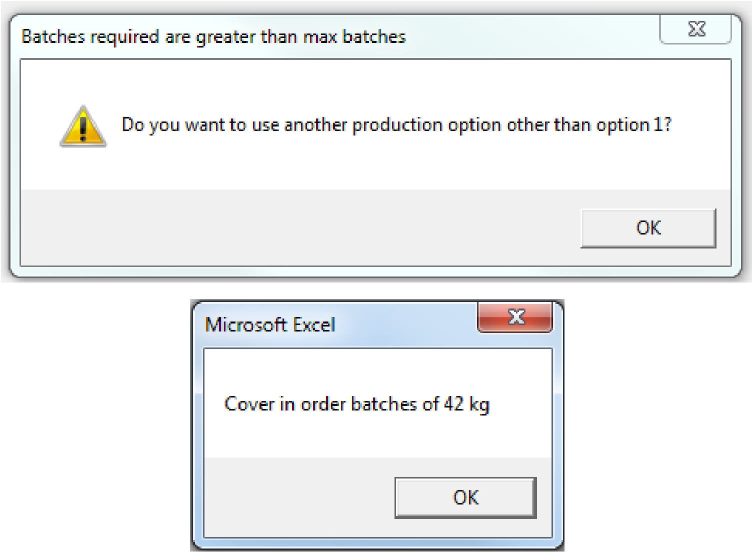


Figure 5.6: Message boxes to inform user.

The first message box in Figure 5.6, informs the user that the number of batches required to cover the order is greater than the allowed maximum number of batches. The message box also asks the user whether he/she wants to use another option rather than option 1. When the user selects 'OK' on the first message box, he/she wants to use scenarios 2-4. The second message then appears on the screen to inform the user of the order amount they must use to cover the order in smaller order batches.

The user can decide at any stage when on the user form to exit the user form or use the subtract function button. The subtract output button, depicted in Figure 5.2, subtracts the orders' outputs, that the user already selected or covered on the user form, from the orders that have not yet been covered by the user. Thus, by pressing the button the user is informed about the outstanding order weights that still remain to be covered.

This button is given as a choice for the user as in certain situations or certain times of the year the factory does want to produce extra products, so then the user will not use the subtract function button. To illustrate how the button function works, the earlier examples from Figure 5.3 and Figure 5.5 are used. After the subtract output button was pressed the user form updated the order values from Figure 5.3 with the remaining orders as shown in Figure 5.7.

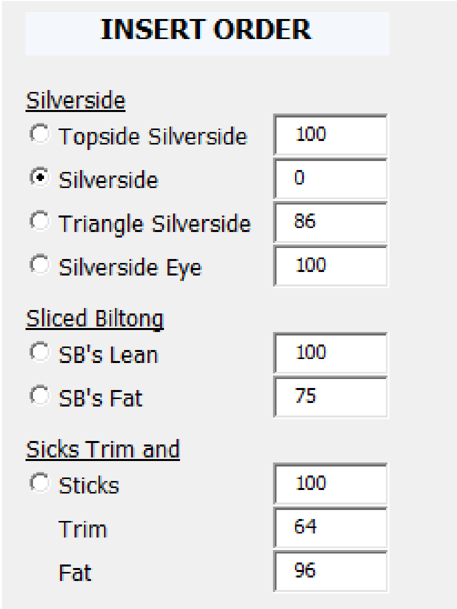
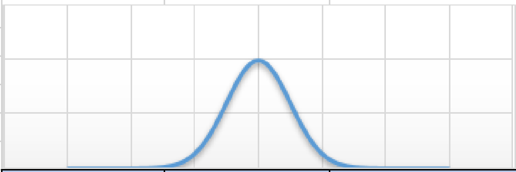


Figure 5.7: Remaining weight to cover orders.

The output of Triangle Silverside, in Figure 5.5, was 14.55kg. This weight is subtracted from the original 100 kg Triangle Silverside order as shown in Figure 5.3. Therefore, the remaining weight rounded up for Triangle Silverside is now 86 kg as depicted in Figure 5.7.

The user can choose at any stage to resume or start a new user form when on the Excel sheet, thus the user form has already been exited. The resume button will have the values previously inserted on the user form and the results from the previous action will stay on the sheets. With the new user form button, the user form is cleared as well as the results on the sheets are cleared.

The user can also make the decisions highlighted in light grey on the process flow diagram in Figure 5.1 at any point in time, when on the user form or Excel sheets. The user can exit and save the Excel results, or they can press the result summary button, depicted in Figure 5.2. This button automatically opens the summary sheet in Excel. Figure 5.8 depicts the summarised results for the Silverside example.

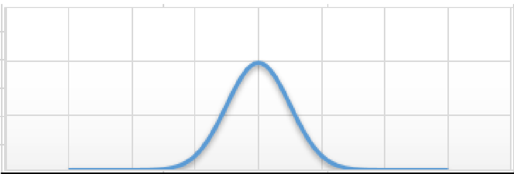


Order:	Silverside			Min STD	Avg	Plus STD
Order weight (kg):	100.00	Input (kg)	Silverside Flat	156.07	185.81	215.54
		Option1	Time1	7 min 46 sec	9 min 17 sec	10 min 48 sec
			Cost1	R 31.06	R 37.14	R 43.22
		Option2	Time2	7 min 16 sec	8 min 38 sec	10 min 0 sec
			Cost2	R 29.07	R 34.54	R 40.02
		Option3	Time3	7 min 8 sec	8 min 31 sec	9 min 54 sec
			Cost3	R 28.53	R 34.09	R 39.62
		Option4	Time4	7 min 8 sec	8 min 31 sec	9 min 54 sec
			Cost4	R 28.53	R 34.09	R 39.62

Figure 5.8: Screenshot of results summary for Silverside example.

From the results summary depicted in Figure 5.8, the results for the standard deviation are provided as reasoned in Section 4.3.1. Management can then decide between the range of input weight required for the order and what amount they want to order from suppliers. They can also consider the range of processing times when planning their production.

From this example in Figure 5.8, the different options or scenarios do not have a big influence on the processing time. For a larger order of Silverside, the influence of the different scenarios is more significant. For certain orders the influence of the different scenarios is significant even for smaller order sizes. For example, for a Topside order of 100 kg the influence of the different scenarios on the processing time are more significant as illustrated in Figure 5.9.



Order:	Topside Silverside				Min STD	Avg	Plus STD
Order weight (kg):	100.00		Input (kg)	Topside	209.17	262.53	315.89
		Option1	Time1	1,2,5 done	13 min 13 sec	17 min 12 sec	21 min 10 sec
				1, 7, 9 done	18 min 57 sec	24 min 46 sec	30 min 33 sec
			Cost1		R 80.20	R 104.87	R 129.51
		Option2	Time2	1,2,5 done	11 min 52 sec	15 min 36 sec	19 min 17 sec
				1, 7, 9 done	15 min 39 sec	20 min 28 sec	25 min 16 sec
			Cost2		R 69.05	R 90.98	R 112.72
		Option3	Time3	1,2,5 done	11 min 40 sec	15 min 17 sec	18 min 54 sec
				1, 7, 9 done	15 min 39 sec	20 min 28 sec	25 min 16 sec
			Cost3		R 68.18	R 89.68	R 111.16
		Option4	Time4	1,2,5 done	11 min 40 sec	15 min 17 sec	18 min 54 sec
				1, 7, 9 done	17 min 24 sec	22 min 51 sec	28 min 17 sec
			Cost4		R 71.24	R 93.86	R 116.44

Figure 5.9: Screenshot of results summary for Topside order.

The production management model, as discussed in this section, is flexible as it adapts to different order sizes, number of employees available and their rates, different input cuts, input weights and processes. Hence, the results are dependent on the user's input and the results adapt according to input.

5.1.1. Potential Benefits

This section discusses the potential benefits for the company when they use the developed production management model.

The information provided with the production management model could be used to assist with:

- Inventory management.
- Decision making.
- Saving cost: Decisions that are being made to determine what cut must be used, are based on the cheapest cost/kg - taking into account the labour cost as well as the throughput rate.
- Factory management: The throughput rate will be known for the management to determine whether targets/demand can be met in a given time frame.
- Handling orders: Factory will know exactly what amount of raw meat to order to meet demand and the time required based on the processes they want to use to cover an order.
- Information can be used for line balancing, identifying bottlenecks and/or factory layout configuration as the time per process are given as part of results.

As the production management model will use cycle times to provide and manage the information discussed above. It can be stated that the production management model will contribute to the following potential benefits identified by Nadarajah et al., (2008):

- Increased throughput;
- Reduced costs;
- Streamlined processes;
- Schedule integrity;
- Improved on-time delivery;
- Reduced process variability and
- Improved communication.

The following waste, as discussed in Section 2.6.2, can be reduced through the production management model:

- Unnecessary inventory: The production management model will manage the required inventory needed to produce the customer's order.
- Overproduction: The production management model will help to manage production and can be used to prevent overproduction as the input required per order is determined.
- Inappropriate processing: The production management model will determine the workers' division per process, in order to establish the best process sequence to manufacture a certain product order.
- Time and waiting time: By determining the fastest process time and the number of workers required at specific operations, the operation time wastage and waiting time are reduced.

This section provides a description of how the production management model works and the information provided by the model is also discussed. Based on the information given by the production management model, the section ends with the potential benefits for the Biltong Factory when using the production management model to manage their production of wet products at the 'Wet Factory'.

From the discussion above, it is clear that the production management model will assist to: Determine the shortest manufacturing time to produce a certain order, estimate cost to manufacture an order considering labour costs and determine the amount of raw meat product required to produce an order. Hence, the aimed function discussed in Chapter 4 was achieved in order to ultimately strengthen the factory's competitiveness through increased efficient operations in the 'Wet Factory'.

The production management model discussion used performance measurement data to determine the scheduling and process routings that adapts according to the orders received to achieve flexible, efficient operations, and competitiveness. Thus, factory's cutting or meat preparation process of the product family with the highest sales percentage, can be managed more efficiently with the developed production management model.

The next section discusses and presents the generic approach developed to help guide South African SMEs with the process of developing an improvement tool to ultimately increase their competitiveness.

5.1.2. Production Management Model

The final model that was developed for the Biltong Factory is provided on a flash drive that is attached to the hardcopy of this thesis document. A video that showcases the use and interaction with the model is also provided on the same flash drive. In the video, different input values are used when compared to the model screenshots provided and discussed in Section 5.1.

5.2. Generic Approach

The aim of this study, as mentioned in Section 1.2, 'to develop an approach to guide the process that a typical South African manufacturing SME can use to develop an improvement tool in order to increase their competitiveness.' The development process used to design the generic approach is discussed in the subsequent section. The developed generic approach to guide South African SMEs with the process of developing an improvement tool to ultimately increase their competitiveness, is illustrated in Figure 5.10.

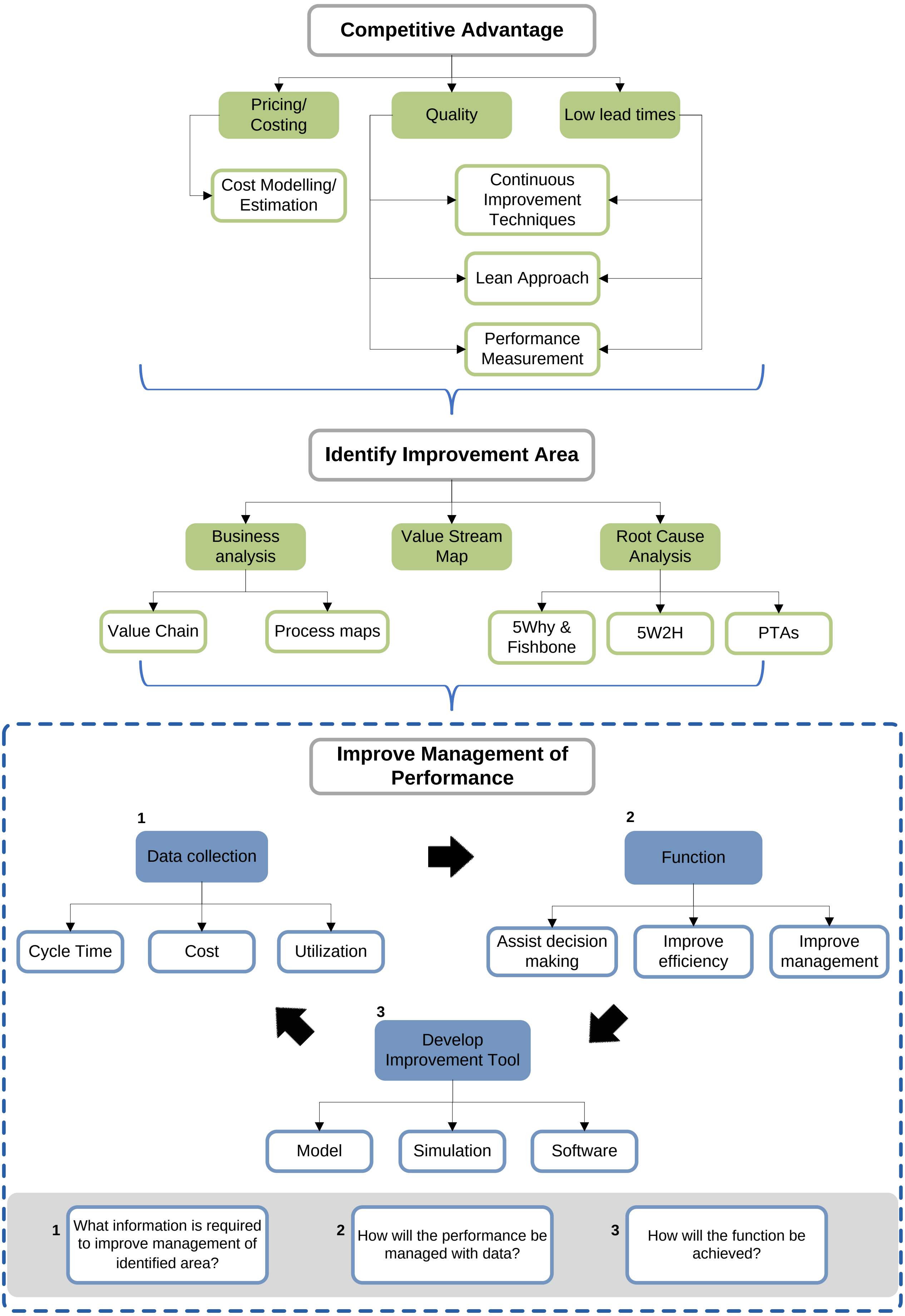


Figure 5.10: Generic approach for developing a tool to increase competitiveness.

The generic approach provides a method that manufacturing SMEs can follow, for identifying an area to implement improvement through a performance management tool to ultimately increase competitiveness. The generic approach aspects depicted can differ for different manufacturing SME companies, as manufacturing as a whole covers a wide range of industries.

Hence, the approach steps do not need to be followed as shown, or can be replaced by different methods that are better suited for the company. At each phase the company can ask: How would this be interpreted in our case?

The first phase is to conduct research on competitive advantage concepts and tools. This is done to guide the process to analyse the business in order to identify an area that requires improvement. The three pillars for the research are the main aspects for a competitive edge namely; pricing, quality and low lead times. The company can conduct this phase by asking: What defines our competitiveness?

The second part of the approach consists of analysing the enterprise through the company's Value Chain and process maps. This analysis is conducted to identify an area that requires improvement. The area requiring improvement can then be identified by using the following tools: Value Stream Mapping (VSM) and/or Root Cause Analysis (RCA).

The RCA can consist of the Five Why and Fishbone method, the Problem-tree analysis (PTA) method or the 5W2H method, with 5W being the questions: What? Why? Where? Who? When? and 2H being How? Asked twice. Alternative methods or tools can also be used by a company for example, customer surveys or employee surveys can be used to determine employee or customer problems.

After the area for improvement has been identified a continuous process starts, blocked in blue (as seen in Figure 5.10), in order to refine the development of an improvement tool. The continuous process starts by establishing the data required to improve the management of the enterprise's performance, in the specific identified area.

The type of data or information required can be determined by asking the question in the light grey area shown in Figure 5.10. What information is required to improve the management of identified area? This is asked as the data can differ for each company and the data also depends on the area the company wants to improve.

The next step of the continuous process is to establish how the data can be used to manage the performance more efficiently. This can be determined by asking the question as depicted in the approach. How will the performance be managed with data? This step consists of determining the function that the collected data must accomplish to increase the company's competitiveness. By determining the function that the data must accomplish, it provides a clear view of what the production management model must achieve before the actual tool development starts.

Step 3 of the sequential process is to develop the improvement tool. By asking the following question the type of tool to be developed can be determined: How will the function be achieved? Hence, the goal of the tool is to meet the determined function that was established by considering the problem to be solved. The problem is first clearly determined before the tool development starts as the required research, problem area identification, data required, and production management model function are established in order to develop the production management model with a clear purpose.

The continuous process starts by going through each of the steps once. When the tool development phase starts, the process of data collection, determining function and tool development becomes continuous. These processes are interconnected to ultimately refine the developed tool. Thus, while developing the improvement tool the realisation of outstanding data can be made. The new data then needs to be collected and this new data will also change the determined function and in effect also the tool development procedure as the new function needs to be accommodated.

5.2.1. Generic Approach Development

The generic approach was developed based on a continuous process to refine the approach. The continuous process, as depicted in Figure 1.1, consists of the literature review, use case analysis and production management model development (Chapter 2-5).

This sequential process was used to refine the generic approach continuously to ultimately develop the final generic approach. This process can be seen as the methodology approach depicted in Figure 2.20 were refined, to ultimately design the generic approach discussed previously. Hence, the generic approach was, in effect, implemented in the Biltong Factory to develop the production management improvement tool.

Figure 5.11 illustrates how the developed approach was executed in the research study as indicated in red.

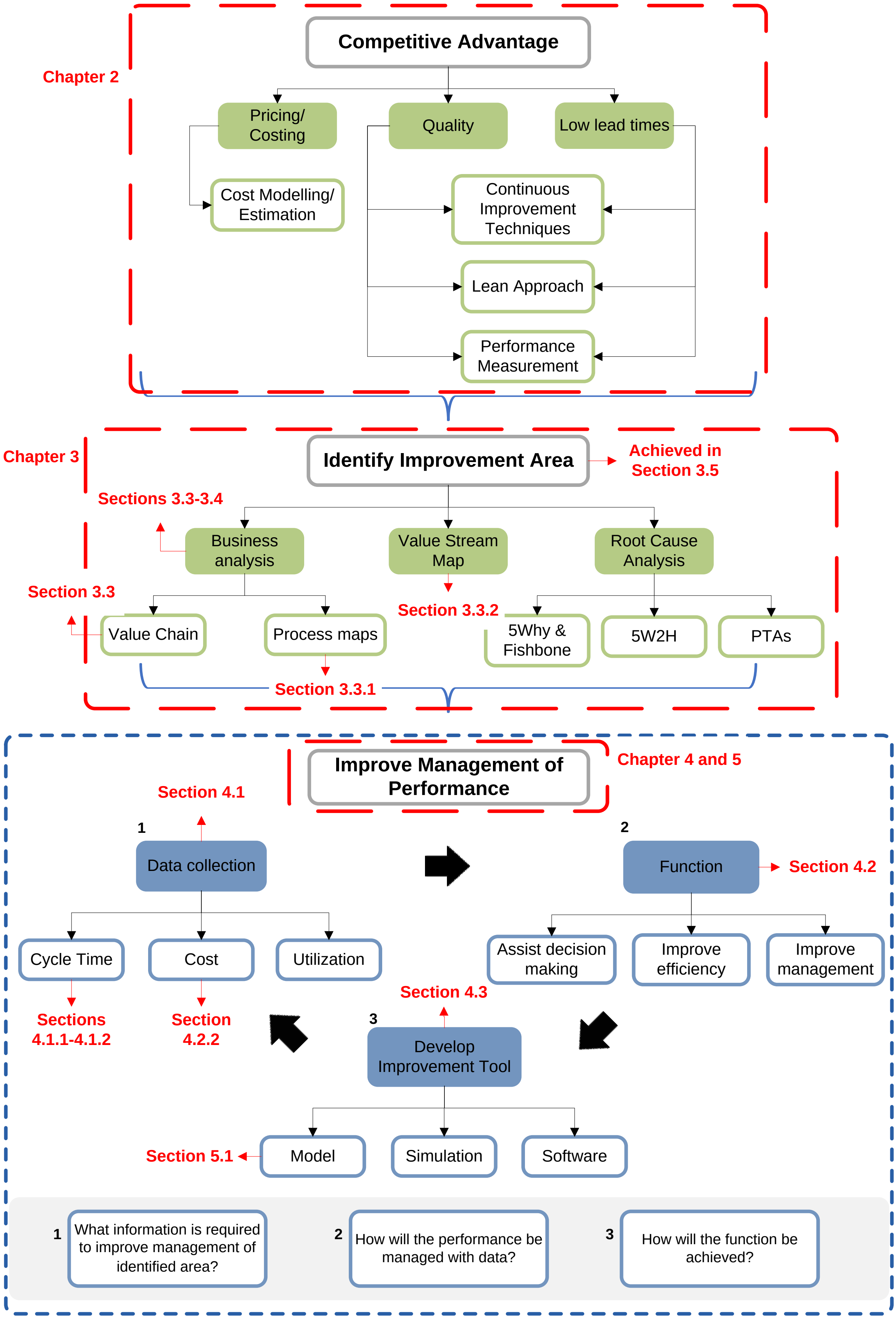


Figure 5.11: Develop approach as used in research study.

5.3. Chapter 5 Summary

Chapter 5 illustrates the production management model results and concludes with the potential benefits that the production management model can provide to the Biltong Factory. Lastly, the primary aim of this research study to developed generic approach for South African manufacturing SMEs to follow, to ultimately strengthen their competitive advantage through improved performance management to increase efficient operations, was presented and discussed. Chapter 6 will discuss the validation to confirm the presented solutions from this research.

Chapter 6

Validation

This chapter is concerned with the validation of the solutions presented in this research generic. Firstly, the production management model roadmap is validated through an article that was selected for publication in the South African Journal of Industrial Engineering (SAJIE). Secondly, the developed production management model is validated through an interview with one of the Biltong Factory's owners. Thirdly, the generic approach was validated through a questionnaire that was completed by industry experts.

6.1. Model Function Roadmap

The journal article titled "A conceptual framework to increase competitiveness in a Biltong Factory" was based on the content of Chapter 3 and 4. The article was selected for publication in SAJIE and as part of the 29th SAIIE (South African Institute for Industrial Engineering) conference. Thus, indicating that the reviewers agreed that the conceptual framework developed for the Biltong Factory would be of significant help for South African manufacturing SMEs to analyse their own operations. The journal publication serves as validation that the literature methodology that was used to analyse the factory to determine the target area for improvement, required performance measurement data and the developed conceptual framework to increase the factory's competitiveness is valid.

The journal article is attached in Appendix G. The article information is as follow:

- **M. Henning**, D. Hagedorn-Hansen, K.H. von Leipzig, "A conceptual framework to increase competitiveness in a Biltong Factory", *South African Journal for Industrial Engineering* (SAJIE), October 2018.

6.2. Production Management Model

The following validation for the developed production management model is based on an interview with one of the owners of the Biltong Factory where this study was conducted. The feedback obtained from the questionnaire, regarding the generic approach, further validated the statements in the interview. The original questionnaire feedback from the owner of the Biltong Factory is shown in Appendix H, under expert feedback number 8.

Some of the questionnaire feedback included the following:

- The approach helped the Biltong Factory to increase production, save on overtime and bring their input cost down. Thus, resulting in better profits and being more competitive in their market.
- That they will use the approach in the future as the approach already helped them to look at other areas in their company to improve cost savings and be more competitive.
- The approach is generic and manufacturing SMEs needs to work better and smarter to stay competitive.

The following is a direct extract from the interview conducted, regarding the developed production management model, with the owner of the Biltong Factory.

> "For a competitive edge our production plays a key role. We can't pay less for our raw meat cuts supplied and we also can't ask more for our products, as this could lead to us being outpriced in the market. Thus, the only way we can make more money and be more competitive is by improving our production processes.
>
> The model aimed at the wet factory's production are justifiable for the following reasons:
>
> - The improvement focused on the wet factory's production influences the whole production process, therefore the impact is significant.
> - The dry factory is completely dependent on the wet factory. When the dry factory receives their products faster from the wet side the drying units can be filled faster, thus in effect we produce our end products much quicker.
>
> We are used to operate in our own set ways. The information provided by the model and the duration of the student's involvement at the factory, opened our eyes and gave us a different outlook on the production processes and our current operation model. It also formed part of the foundation that were needed by us to drive and implement change and was the reason why we implemented changes so quickly. Hence, the model developed, and the duration of the student's involvement definitely was a stepping stone to revolutionise our production and already have strengthened our competitiveness.
>
> The information provided with this model are relevant for our company as we must be very flexible as the production environment can change fast and we must adapt fast. The data provided were also valid and made sense to us. We could see the power of the information provided by the model and it definitely could assist with:

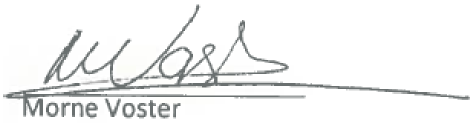
- Structured production planning. The production planning of the wet factory influences the whole production system (all processes wet and dry side). As we now know, with the model, exactly the amount of product that will be finished in a certain time frame for the next processes to start at the wet and dry side.
- The production management requires constant decision making. This model assist with the monitoring of those decision.
- The model definitely helps with management as the factory management was based on experience only. With the model's data if the experienced person is replaced or sick an outside person can use the model to assist with management to ensure that the orders are delivered in time.
- The model information can help with inventory management as the exact input and output weights are given. This information also reduces the risk of overproduction.
- We could use it to determine whether we ask enough for our products or whether some products that are produced quickly make up with its selling price, for the products that are costlier to produce.
- The data helps to determine the most efficient way to produce our orders. This aspect is crucial to satisfy our customer needs. Cost is one aspect but if the products aren't delivered on time, we could lose our clients.
- The cost information helps to understand the production cost on the financial sheets better, as the production cost can now be associated with each product.

We had to implement change fast as our factory were running at max capacity and we couldn't accept new client's orders. Therefore, there wasn't time to implement the model to see the improvement in production. The main use of the production management model developed by the student was to assist us with decision making regarding changes we wanted to implement in the wet factory's production process. We wanted to start implementing change at the wet factory specifically because of the big influence the wet side has on our end product throughput.

The production innovation led us to invest in new machines and ordering cleaned meat cuts from suppliers. The investment in the machines together with the cleaned meat cuts ordered eliminated various processes that were highlighted by the model as bottlenecks and costly processes. Therefore, the model's information also helped us to justify the processes to eliminate as well as the cost of the investment made in the new machines.

The influence of the implemented changes has been immense as we have not yet had to operate overtime to keep up with orders even in November when the factory normally works 2 shifts to produce enough stock for December. We also had our biggest month yet!

<u>Future improvements:</u>
With the benefits of the model as listed above, we aim to collect the same type of data for our new production processes, in next year, to enable us to build a model that provides the same information than the model of the student. We realise the great impact it can have on our production management and that it will further increase our efficiency and in effect strengthen our competitiveness. We also plan to improve the dry factory's processes to make it easier to keep up with the fast throughput from the wet factory."



Morne Voster

From the information presented in the interview it can be said that the developed production management model did assist the Biltong Factory with decision making to determine which processes can be eliminated to justify the cost of investment in machines and the cost of ordering cleaned meat cuts (Voster, 2018).

The planned function of the production management model was achieved as the interviewee indicated that the information provided through the model can assist with determining (Voster, 2018):

- The shortest time to cover an order;
- Precision cost estimates and
- The required raw meat to produce order.

The potential benefits in Section 5.1.1 was also obtained as the interviewee stated that the information provided through the model can also assist with (Voster, 2018):

- Structured production planning;
- Production management;
- Decision making;
- Inventory management;
- Production efficiency and
- Cost estimation.

The owner of the Biltong Factory also stated that the production management model will also be used as a basis for further continuous improvement at the Biltong Factory (Voster, 2018). They plan to collect the same type of data for their new processes and also they aim to improve the production process of the 'Dry Factory' on the same basis (Voster, 2018).

6.3. Generic Approach

The generic approach was validated through questionnaires that were given to nine industry experts whom have done consulting work for the manufacturing sector or are working currently in the manufacturing sector. The occupation of the experts is summarised below.

Table 6.1: Experts and their occupation.

Expert	Occupation	Industry
1	Operation Manager	Food processing
2	Business Consultant	ERP Systems
3	Performance Improvement Consultant	Accounting
4	Owner/Director	Manufacturing
5	Consultant Business Analyst	Consultancy
6	Production Manager	Container manufacturing
7	Production Manager	Ablution Manufacturing
8	Owner/Director	Biltong
9	Consultant/Logistics Manager	Wine

The original questionnaire and feedback from the experts are in Appendix H. The following table summarise the results conducted from the questionnaire.

Table 6.2: Questionnaire results summary.

Question	Results Summary
1.) What is your occupation description at your current company? Example consulting, project manager etc.	Director/Owner: 2 Business Consultant: 3 Production/Operation Manager: 4
2.) Do you have some experience in the manufacturing field?	Yes: 9 No: 0
3.) Have you ever had to implement improvements to increase competitiveness in a (your) company?	Yes: 8 No: 1
4.) Can the competitiveness of a manufacturing SME in SA be improved by using the approach presented?	Strongly Agree: 5 Agree: 4 Disagree: 0 Strongly Disagree: 0
5.) Does the approach cover the necessary information to implement improvements in a manufacturing SME?	Strongly Agree: 4 Agree: 4 Disagree: 1 Strongly Disagree: 0
6.) Is there any other information that you would deem necessary for the approach to include, other than those presented?	Yes: 5 No: 4
7.) Is this approach generic for manufacturing SME's in South African context to increase competitiveness?	Yes: 7 No: 1 Yes and No: 1
8.) Could you use this approach in your working environment?	Strongly Agree: 5 Agree: 3 Disagree: 1 Strongly Disagree: 0
9.) What from this approach have you used previously in your working environment?	-Root cause analysis and using reliable data make decisions fast and accurate -The process of starting with a competitive advantage analysis and drilling down to identify specific processes which need improvement. -All of it
10.) Has this approach introduced or informed you of something new that you would use in the future to implement improvement?	Yes: 6 No: 3 Have applied various parts of this approach but not yet applied it as a whole as this approach suggest. Thus, the approach is very useful.
11.) Could this approach possibly help you in future for implementing improvement ideas to increase the competitiveness of a company?	Yes: 7 No: 1 Yes and No: 1

Questions	Results Summary
12.)General comments?	-Well-developed model for any SME. The approach is generic and can be applied to a wide range of areas. -As a business owner I realise the importance of having access to such an approach.

Some interesting aspects from the feedback are summarised in the following discussion. The important aspect of data collection for decision making was highlighted through various responses. They also said that not enough relevant data is being captured in most South African SMEs. The feedback also stated that the approach is generic as it is simple to follow and can be used to guide the process to determine where and how to improve. Moreover, the results indicated that the approach can have a great impact on competitiveness and can be applied to a wide range of manufacturing SMEs.

For question 5, one response indicated that they disagree that the approach does cover all the necessary information. They indicated that the following is required to be included in the approach, "What are the limits to the scope of the solution? Such as initial cost." The results did not indicate a similar response for question 6 asking what information was deemed necessary to include in the approach. The results ranged from measuring raw material quality, including the SCOR model and including market/industry-related data. The approach also introduced the experts to new concepts or ideas (question 10) and varied from certain parts (simulation or determining the data function) to the whole approach.

One response also said that in practice it is seldom as 'formal' as the presented approach to increase competitiveness and responded 'yes and no' to question 7 and also disagreed to question 8 and 11. The expert further stated that "competitiveness will not be changed by implementing 'formal' procedures in SMEs. As competitiveness is a culture of a nation and have to be fixed from the bottom to the top. Starting at all the simple things, a proper school system, proper training institutions, proper work ethics, a government that incentivise excellence."

Only one response indicated that the approach is not generic by stating that, SMEs generally don't have adequate data collection tools as such miss out on efficiencies that could be gained through Industry 4.0 technologies. 90% Of the experts indicated that the approach could help them in the future for implementing improvement ideas to increase competitiveness. Some comments included that the approach can be beneficial even for top management, to evaluate where they are and where they want to be.

All of the experts chose the 'agree' or 'strongly agree' option for question 4 (Can the competitiveness of a manufacturing SME in SA be improved by using the approach presented?). Thus, all the experts agreed that the competitiveness of a South African manufacturing SME can be improved by using the generic approach.

From the feedback it can be concluded that the developed generic approach is indeed generic and there is a need for an approach like this. As the experts indicated that the approach would help them to implement improvement to increase competitiveness in a company. Although there was some feedback that disagreed with certain statements, the overall response was positive and all the information the experts deemed necessary to be added to the approach was not uniform or the same. Thus, indicating that the approach includes all the required information in order to increase the competitiveness of a manufacturing SME.

6.4. Chapter 6 Summary

This chapter confirms that the solutions presented in this study is valid. The conceptual framework specifically developed for the Biltong Factory to increase their competitiveness was validated through an article that were selected for publication in SAJIE. The production management model was also validated through an interview with one of the owners of the Biltong Factory. Lastly, the generic approach developed to guide manufacturing SMEs with the process of developing an improvement tool to increase competitiveness was validated through a questionnaire that were answered by 9 industry experts.

Chapter 7

Conclusion and Recommendations

Chapter 7 reports the conclusions and findings of the research study. An overview of the project is first provided, then the chapter discusses the achieved objectives that were defined in the introduction chapter Section 1.2. A conclusion about the research study then follows. The study is then concluded with recommendations and future work.

7.1. Project Overview

The study consists of 6 chapters. Chapter 1 introduces the problem that this research aims to solve. This chapter also discusses the project objectives and methodology followed to achieve these objectives. The manufacturing industry's competitiveness is affected by global changes in the landscape, which require them to compete with international companies.

Although there is a movement towards the Fourth Industrial Revolution in the South African context there exists a variety of challenges for implementing Industry 4.0. Thus, typical South African manufacturing SMEs are not on route to implement Industry 4.0, as they either cannot or do not want to implement Industry 4.0 principles and technologies yet. The primary aim for the research project was, therefore, to develop an approach for these types of typical South African manufacturing SMEs which can be followed in order to increase their performance and in effect increase their competitiveness.

Chapter 2 presents an overview of literature previously conducted. Research on manufacturing industries was done to provide a background and understanding on manufacturing. According to Mayer and Nusswald (2001), an enterprise's success is measured in terms of three economic global goals: High quality, low lead times and low costs. These three main goals were the foundation for the conducted research. Based on these goals, the main cornerstones for achieving competitive advantage were identified as: Cost and pricing, quality, continuous improvement, and performance measurement. The relationship between the cornerstones' and 3 main goals for competitive advantage were depicted in Figure 2.3.

The first parameter for competitive advantage, cost and price, was further investigated by conducting a literature study on the types of manufacturing costs and cost-modelling techniques. For continuous improvement and the quality cornerstones, different continuous improvement techniques were analysed, and further research was conducted on Lean.

The Lean concepts, such as cost reduction and flow, also refer to the costing or pricing as well as the performance measurement cornerstones of competitive advantage. Tools to identify problems were also considered. These tools included Root Cause Analyses (RCA) and Value Stream Mapping (VSM). To implement Lean aspects of assembly line design, including the importance of performance measurements, and more specifically cycle time, were also studied.

The conducted literature was then used to develop a use case methodology to guide the process of analysing the Biltong Factory for which a production management model was developed. The use case was analysed in Chapter 3 to determine an area that would have the greatest impact on the company’s efficiency and in effect their competitiveness when improved.

Chapter 3 first presented the ABC application steps that were used together with the use case analysis methodology to drive the process of analysing the use case, in order to develop a production management model for them.

Part of the analysis process was to develop a Value Stream Map for the factory, in Section 3.3.2, to highlight certain value-added processes that are crucial to consider as these processes can influence the company’s profit margins immensely. To determine the specific product family to be targeted for improvement, a product-quantity analysis was done, by determining the Biltong Factory’s products that have the highest sales’ volumes. The products identified contributes to 80% of total sales.

To establish whether these products were part of a product family, the products’ production routing maps were developed and are illustrated in Appendix C. By comparing these maps, it was clear that the products do make use of similar processes and equipment in order to produce the wet products. Hence, the the products were part of the same product family. The improvement area to be targeted was then identified as the ‘Wet Factory’s’ cutting or meat preparation process. The specific meat cuts to be targeted that were part of the product family were following cuts: Silverside Flats, Silverside A grade, Topside and Flank steak.

After an area for improvement was established, the data required to develop the production management model was discussed in Chapter 4. The number of time study replications required to calculate an average output rate per process were determined through a single Sample t-Test calculation in Statistica. The results in Figure 4.3 showed that 30 replications were required.

The experiment steps were then determined to measure the input weight, cycle time, and output weight for each process for 30 replications. Once the data required for the model was determined, the production management model function was then established. The production management model function roadmap, in Figure 4.5, indicated the methodology that was followed in order to determine the area for improvement and model function for the Biltong Factory's model. Chapter 4 then further discusses the production management model development which included the experimental data analysis and model formulation.

After the function, data required, and model formulation were established, the production management model VBA was then developed for the use case. Chapter 5 first presents the production management model results and explains how the model works. From the discussion it is clear that the production management model adapts according to the user's input, thus, making the model flexible. The planned function of the production management model was also met as the information provided determines:

- The shortest time to cover an order through determining the most efficient sequencing of processes and division of workers.
- The production management model estimates the cost to manufacture the raw meat product.
- The production management model determines the input weight required based on the inserted order.

Chapter 5 then discussed potential benefits for the factory when using the developed production management model. The chapter is then concluded with the developed generic approach discussion, in Section 5.2. The generic approach was developed based on a continuous process that consisted of reviewing literature, analysing the use case and developing the production management model. The continuous process between these phases was used to refine the final generic approach. The next step of the research study was to determine whether the solutions presented by the study was valid.

Chapter 6 consists of the validation to confirm that the following solutions presented in this study are valid. The roadmap that was developed to determine the production management model function for the use case was presented in an article. The information presented in the article was validated as the article was peered reviewed and selected to be published in the South African Journal of Industrial Engineering (SAJIE).

The developed production management model was validated through an interview conducted with one of the owners of the Biltong Factory. From the interview it was clear that the production management model and the developing phase gave them a different outlook on their production processes. Therefore, the production management model formed part of the foundation that was required to implement change.

The changes included investing in new machines and ordering the raw meat cuts differently, thus eliminating various processes at the 'Wet Factory'. The production improvement has increased the Factory's throughput immensely leading to their biggest sales month yet. Hence, the production management model developed and the author's involvement, was a stepping stone to revolutionise their production and have already strengthen their competitiveness with the changes they had already implemented.

Lastly, the generic approach's validation was based on a questionnaire that were completed by industry experts. These experts had experience in the manufacturing field, and the results are discussed in Section 6.3. The results' discussion includes the following:

- 90% of the experts indicated that they could use the approach in the future to help them to implement improvement ideas to increase a company's competitiveness.
- All of the experts agreed that by using the developed approach, the competitiveness of a South African manufacturing SME can be improved.
- The important aspect of data collection for decision making was highlighted through various responses.
- Various responses also said that they have experienced that not enough relevant data is being captured in most South African SMEs.

7.2. Achieved Objectives

In Chapter 1 the primary aim of this study are stated in Section 1.2.2, with a set of research objectives to guide the process to achieve these aims. Table 7.1 at the end of this chapter summarises the chapters, sections and page numbers where each of the objectives have been achieved

The first objective is to determine whether there is a need for a guideline for South African manufacturing SMEs, to increase their competitiveness. This objective is addressed in the introduction chapter.

Chapter 1 clearly stated that the global changes in the manufacturing landscape affect South African companies' competitiveness, as they must compete with global competition in international markets. Although, there is great potential for SA to lead Africa in the Fourth Industrial Revolution movement, there are still a variety of challenges to overcome before South African manufacturing SMEs will be on route to implement Industry 4.0. Therefore, to compete with the increased competitive manufacturing landscape, South African manufacturing SMEs require an approach to guide them in developing improvement tools to increase their competitiveness.

The objective, to identify and analyse strategies and tools for increasing the competitiveness of South African labour-intensive manufacturing SMEs, is addressed in the literature study, Chapter 2. The literature conducted addresses competitive advantage concepts and tools to identify an area requiring improvement.

The literature reviewed 4 cornerstones that were identified as the main cornerstones for competitive advantage, namely cost and pricing, quality, continuous improvement and performance measurement. Figure 2.3 clearly summaries how each of the cornerstones are addressed in order to achieve this objective.

The third objective, to develop a production management model for the use case, a Biltong Factory, were achieved through the following sub-objectives. The first sub-objective, to determine whether a Biltong Factory do represent a typical South African manufacturing SME, was addressed through the use case analysis. Through the discussion in Chapter 3 it was clear that the Biltong Factory's working environment is labour intensive, relatively low technology driven and makes use of unskilled workforce.

From Chapter 4 it is also highlighted that the factory did not have performance measurement data for the 'Wet Factory', as data had to be collected through experiments. The company also make use of 80% unskilled workforce and most of the biltong production processes are done manually. Based on these reasons, the use case represents a typical South African manufacturing SMEs.

The sub-objective to determine whether the developed use case analysis methodology can be used to establish the focus area, required performance measurement data, and production management model function for the Biltong Factory, is achieved through the discussion in Chapters 3-4.

To determine the focus area for implementing improvement, as identified in Chapter 3, the following literature was used. The biltong Value Chain was used to determine the segment which the use case is part of. The VSM and value activities literature was used as the Values Stream Map of the Biltong Factory was developed after the value activities were understood and mapped.

The conducted literature on manufacturing and production layouts was used to classify the use case's production. To determine the relationship between the quality versus price aspect in the Biltong Factory's case, various sections from the literature, as discussed in Section 3.5.1, were used.

To determine the meat cuts to be targeted for improvement, the product-quantity analysis and product family literature was used. The area that was identified for improvement in this study has already been improved by the factory and the impact on their competitiveness and throughput has been significant, as stated in the conducted interview in Section 6.2. Thus, the correct area to implement improvement was identified in the use case through implementing the use case analysis methodology that was developed based on literature concepts.

To determine the required performance measurement data, the following literature concepts were used, in Chapter 4: The cycle time literature was used to determine the type of cycle time to be measured, namely the production run time. To determine the number of time study replications required, information about power analysis was used to understand the Single Sample t-Test size calculation, which were done in Statistica.

To determine two of the main functions of the production management model, namely shortest time to cover an order and precision cost estimate to produce a certain order or product, the following literature was used. Activity-Based Costing, as defined in Section 3.1.1, and the manufacturing cost equation from Section 2.3.4 were used as the basis for the production management model's equations. Cycle time improvement, Lean, and cost estimation literature were further used to determine the function of the production management model, as discussed in Section 4.2, to have a positive impact on the competitiveness.

By achieving these sub-objectives, the objective to develop a production management model for the Biltong Factory was achieved. The production management model results are presented in Chapter 5. The validation regarding the developed production management model in Section 6.2 clearly indicated that the model was used to drive change at the factory, which has already increased the Biltong Factory's competitiveness. The developed production management model did assist with decision making to justify the processes to eliminate by investing in new machines and by ordering cleaned meat cuts. The influence of the implemented changes has been immense and increased the Biltong Factory's throughput significantly.

To achieve the final objective of the study, to develop a generic approach, the following sub-objective needed to be achieved. The sub-objective, to determine whether the literature conducted, together with the phases followed to develop a production management model for the use case, can be used to develop the generic approach, was achieved. As a use case analysis methodology, in Figure 2.20, and the ABC application steps discussed in Section 3.1.1, were derived from literature to guide the process to analyse the Biltong Factory.

The approach discussion in Section 5.2 also clearly stated that the final generic approach was developed based on a continuous process that consisted of the literature review, use case analysis and production management model development (Chapter 2-5). As the continuous process consisted of the different phases of the study the approach was in effect implemented in the Biltong Factory in order to develop an improvement tool namely the production management model for them. Figure 5.11 clearly illustrated how the developed approach was executed in the research study. Therefore, through using the literature and the phases followed to develop a production management model for the use case, the generic approach was developed.

By achieving the sub-objective stated above, the primary aim of this study was achieved. As the study presented a generic approach for South African Manufacturing SMEs to follow in order to increase their competitiveness. The presented generic approach was validated through expert opinions and some important aspects from the questionnaire results were summarised in Section 6.3. From the feedback it can be concluded that the approach is indeed generic and manufacturing SMEs can use it to increase their competitiveness. As all the experts agreed that the competitiveness of a South African manufacturing SME can be improved by using the developed approach.

Table 7.1 summarises the achieved objective discussion.

Table 7.1: Research Objectives Achieved.

Research objectives	Chapter and Section	Page numbers
Conduct a literature review to:	Chapter 1 & 2	1-69
1.) Determine whether there is a need for a guideline for South African manufacturing SMEs, to increase their competitiveness.	1.1-1.2.1	1-4
2.) Identify and analyse strategies and tools for increasing the competitiveness of South African labour-intensive manufacturing SMEs.	2.1-2.9	9-67
3.) Develop a production management model for a use case, a Biltong Factory, to increase their competitiveness through improved performance management. By achieving the following sub-objectives:	Chapter 3 & 4 5.1 & 6.2	70-115 116-127 & 133-137
a) Determine whether a Biltong Factory does represent a typical South African manufacturing SME.	3.1-3.5 4.1	70-95 97-102
b) Determine whether the target area for improvement, required performance measurement data and production management model function, can be identified by the developed use case analysis methodology.	3.1-3.5 4.1-4.2 6.1	70-95 97-106 133
4.) Develop a generic approach to guide the process of developing an improvement tool in order to increase competitiveness. By achieving the following sub-objective:	5.2 & 6.3	127-131 & 137-140
a) Determine whether the literature investigated, together with the phases followed in order to develop a production management model for the use case, can be used to design the generic approach.	All	All

7.3. Recommendations and Future Work

For future work at the Biltong Factory, the production management model will need to be updated with the latest performance measurement data of the new processes in order to continue the process to further increase their competitiveness. After this has been done, the improvement impact at the factory can further be analysed with the new data. The performance measurements can be determined for other processes than the cutting or meat preparation process. A production management model can then be built based on the whole company's performance measurement data.

The approach can possible be implemented at different factories to measure the improvement impact. The generic approach could also be further developed by building improvement tools for different manufacturing companies, to include more information and steps in the approach. To further develop the approach, a workshop can be recommended where different companies come together to share ideas regarding increasing performance and competitiveness in order to include more information in the approach.

With the Fourth Industrial Revolution upon us, the approach could also include Industry 4.0 techniques in the future; when the technologies become more accessible. Moreover, a foundation is required to make the transition to implement Industry 4.0 easier for SMEs. A recommendation can also be made to introduce the generic approach to more manufacturing SME companies, as almost all of the experts that participated in the questionnaire indicated that they will use the developed approach in the future to help them implement improvements to ultimately increase a company's competitiveness.

7.4. Conclusion

The global changes in the manufacturing landscape do affect South African companies' competitiveness, as they must compete with global competition in international markets. In order to improve the competitiveness of a manufacturing company and to be competitive in the Industry 4.0 environment, companies need to adopt new methods and technologies. However, this is often a costly venture, and it may not result in a significant return on investment (ROI) for the company. Furthermore, South African manufacturing SMEs has to overcome a variety of challenges that hinders the adoption of Industry 4.0.

To compete with the increased competitive manufacturing landscape this study developed a generic approach for South African manufacturing SMEs, to guide them in developing improvement tools to increase their competitiveness.

The study used a use case, a Biltong Factory, to develop a production management model for them to increase their competitiveness. The developed production management model assisted management with decision making regarding the Biltong Factory's production processes and the factory did achieve increased efficiency and throughput. This was achieved in an ever-changing market by manufacturing more efficiently.

Based on a continuous process followed to develop a model for the use case, the primary aim of the study was achieved as a generic approach was developed. Hence, in effect the approach was applied to the use case. The generic approach's validation stated that (i) the approach is generic for manufacturing SMEs in the South African context and (ii) there is a need for such an approach as the industry experts' obtained questionnaire results indicated that they will use this approach in the future.

Manufacturing SMEs in SA should remain competitive by continuously improving their operations before they are disrupted by the everchanging manufacturing landscape. These companies should start viewing the Industry 4.0 challenges as endless opportunities.

7.5. Chapter 7 Summary

This chapter serves as conclusion to this research project. It first provides a project overview then a description on how the objectives stated in Section 1.2.2 was achieved followed. The chapter is then concluded with recommendations for future work and the research conclusion.

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Appendix A: Product and Cuts Description

Table A.1: Product description

Product Group Name	Abbreviation	Description
Silversides	SS	Big long piece with fat
Silverside Eyes	SS EYE	Big long piece with fat not as wide as normal silverside biltong
Silverside Triangle	Triangle SS	Big piece with fat and has more a triangle shape
Sliced Biltong	SB's	Smaller pieces with and without fat. After drying it is sliced with machine.
Snapsticks	Sticks	Rectangular shaped thin strips
Topside Silverside Lean	Topside SS	Big long piece without fat

Silverside:

Silverside Eye:

Silverside Triangle

Sliced Biltong Fat

(Silverside)

Sliced Biltong Lean

(Topside)

Sticks

Topside Silverside

Table A.2: Cut description

Cut Name	Description
Silverside Flats	Hindquarter, wide grained texture. More fat than topside.
Silverside A grade	Includes the outside flat of hindquarter above rear leg region. From Figure A.1 it will include piece of rump as well. More fat than topside.
Topside	Inner muscle of the thigh. This muscle is tender and lean (little fat).
Flank Steak	From diaphragm, large amount of connection tissue, lean (little fat).

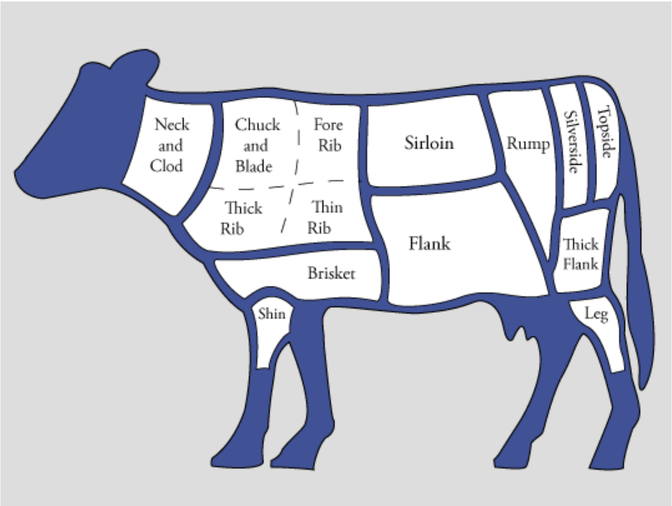
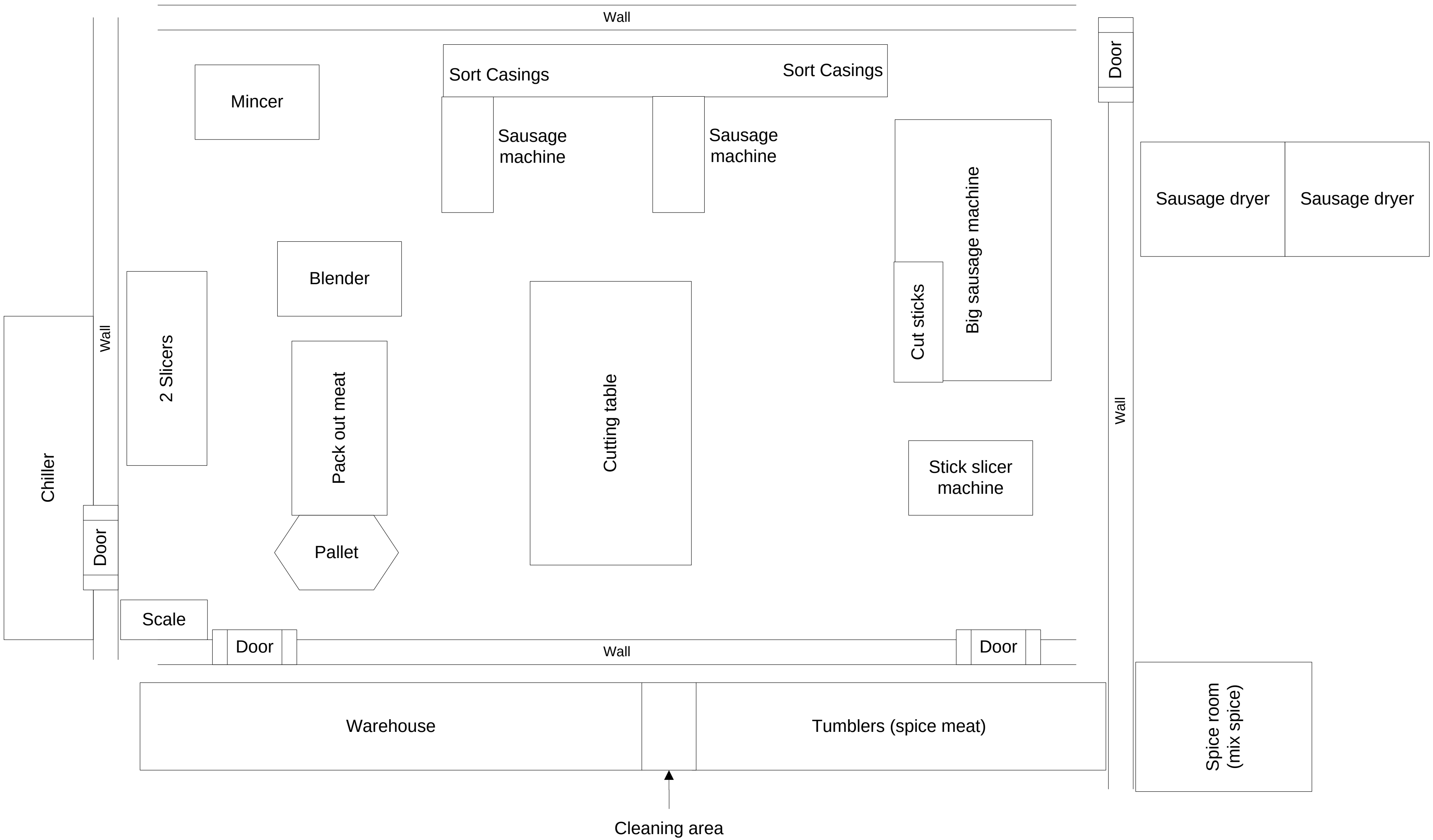


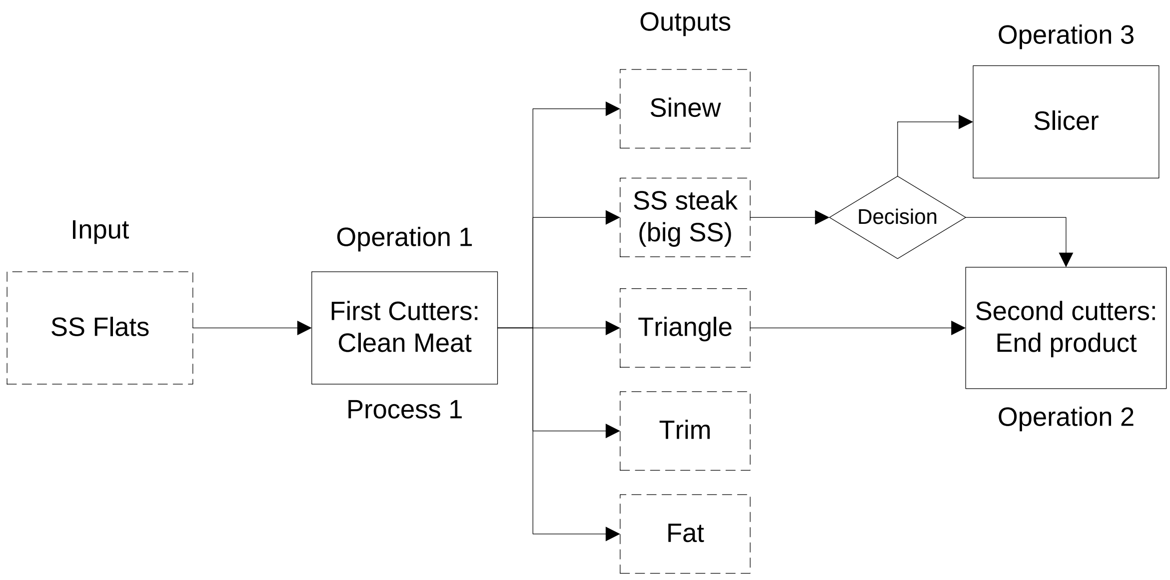
Figure A.1: Illustration of cut of meat

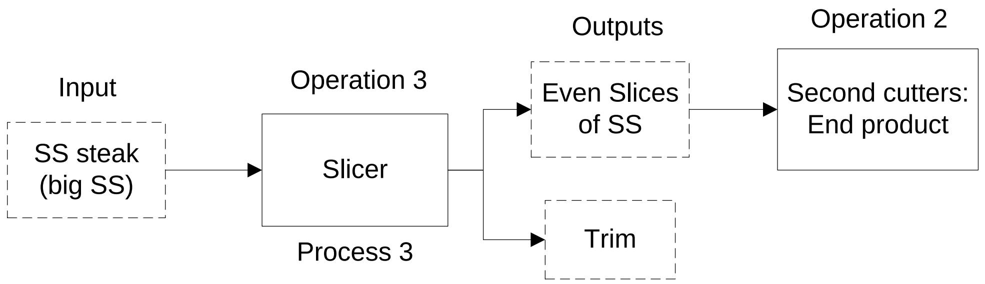
Appendix B: Wet Factory Layout

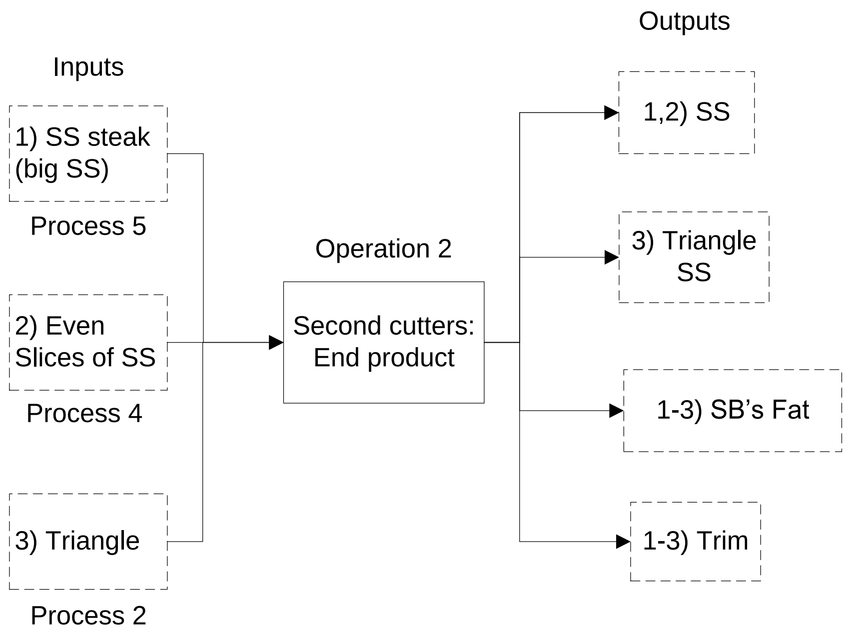


Appendix C: Production Routing Maps

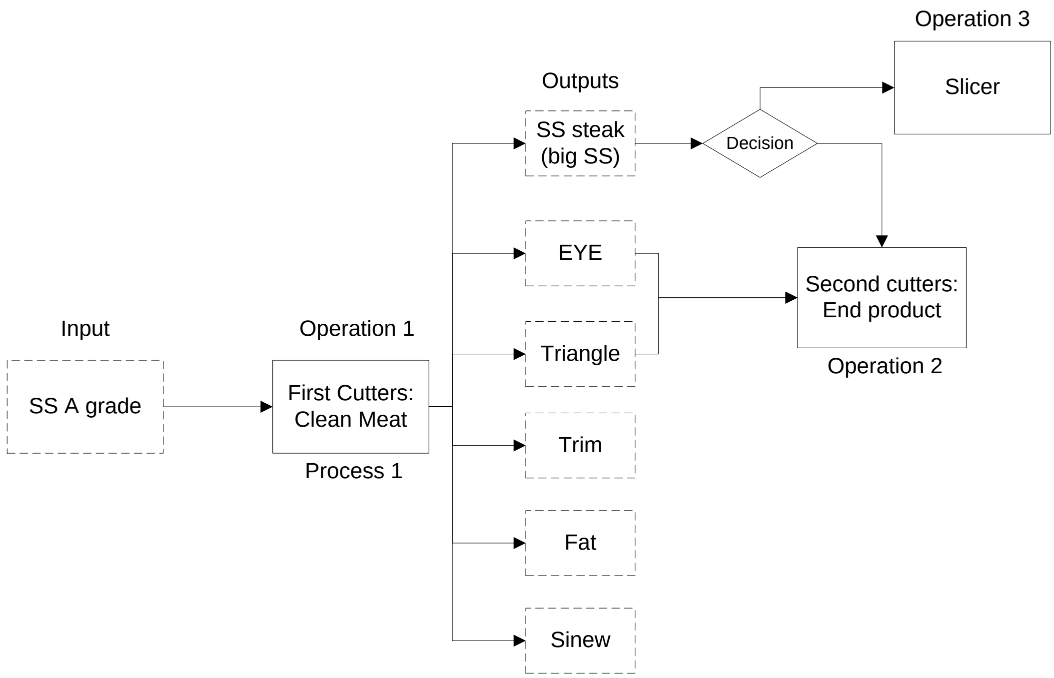
Silverside Flats

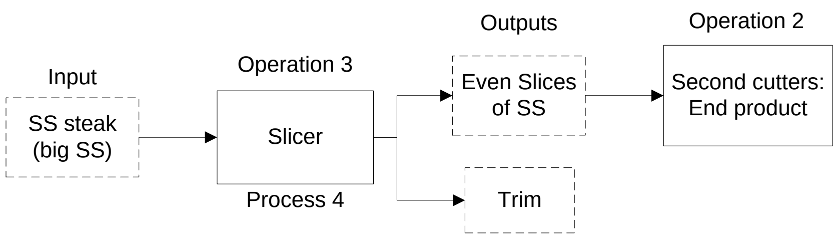


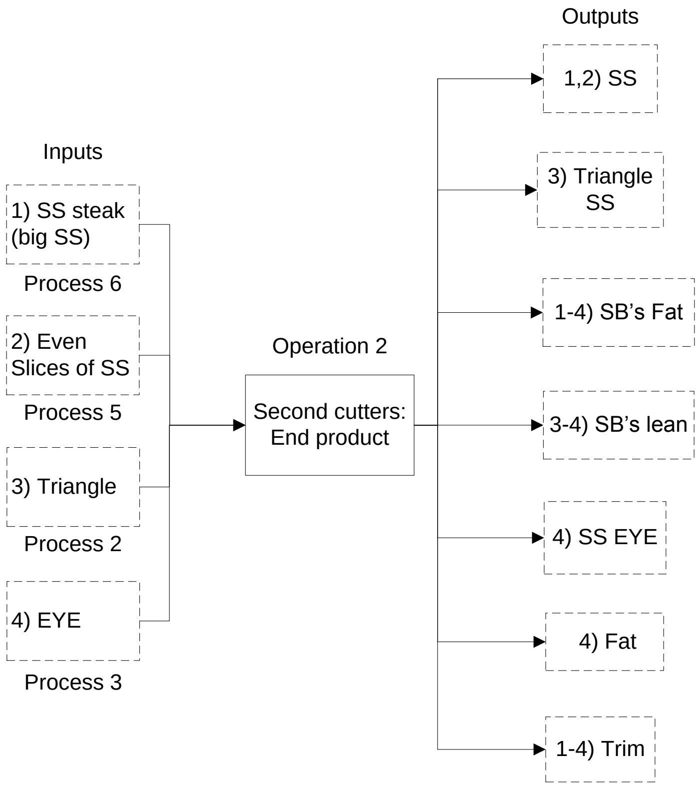




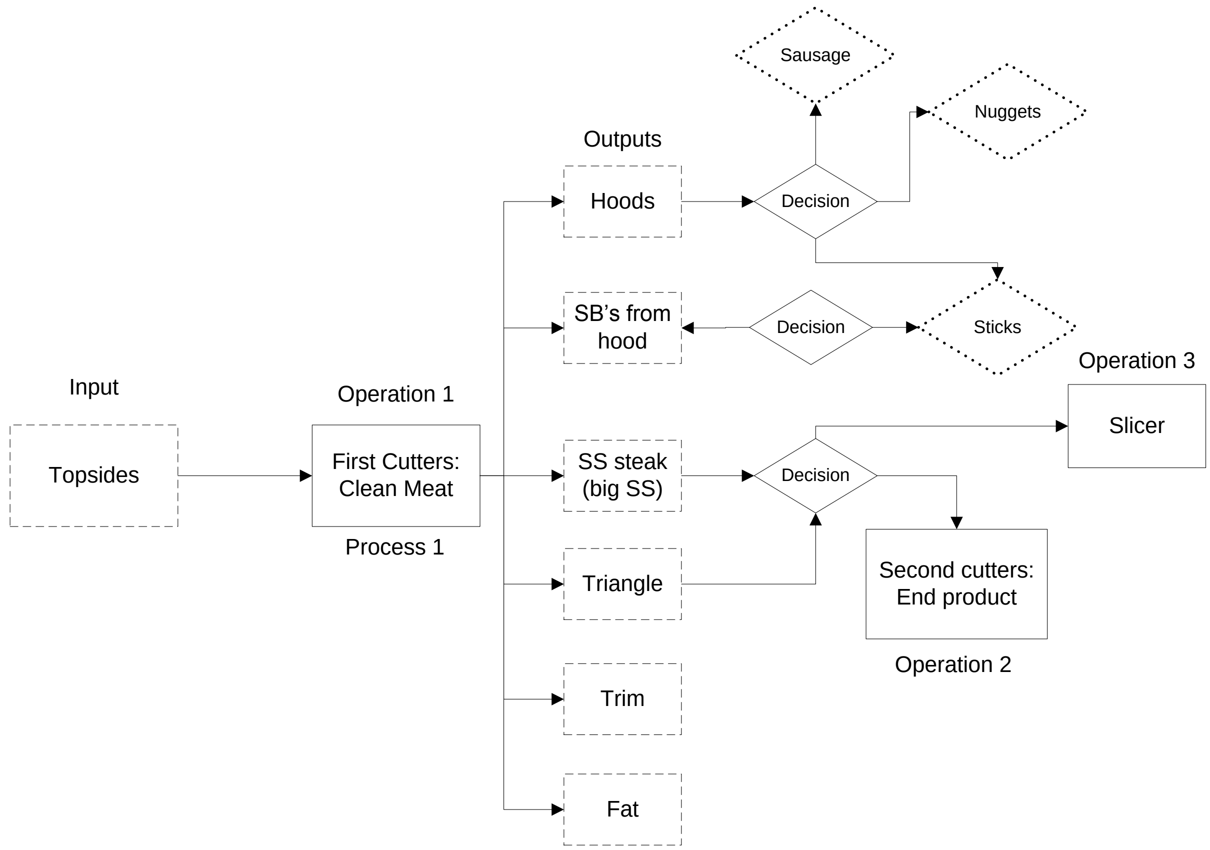
Silverside A Grade

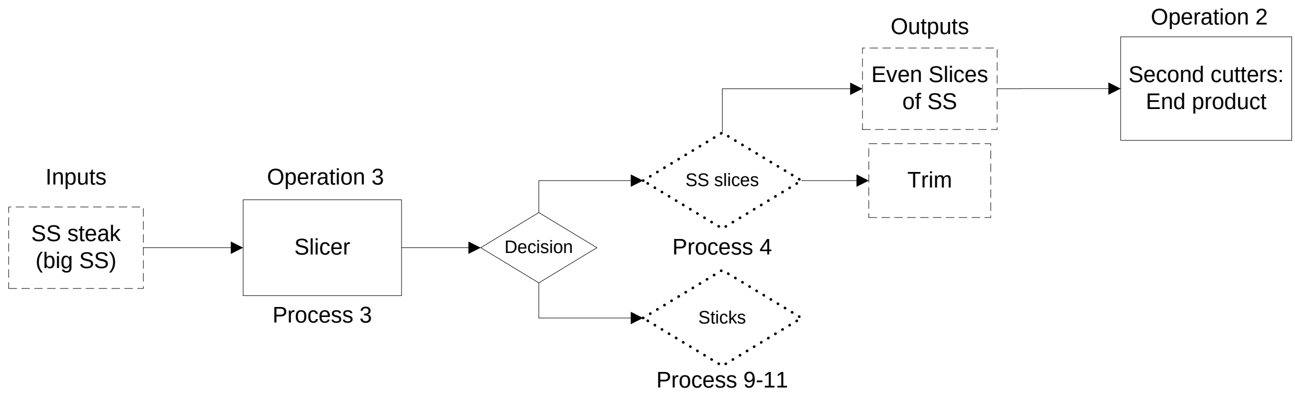


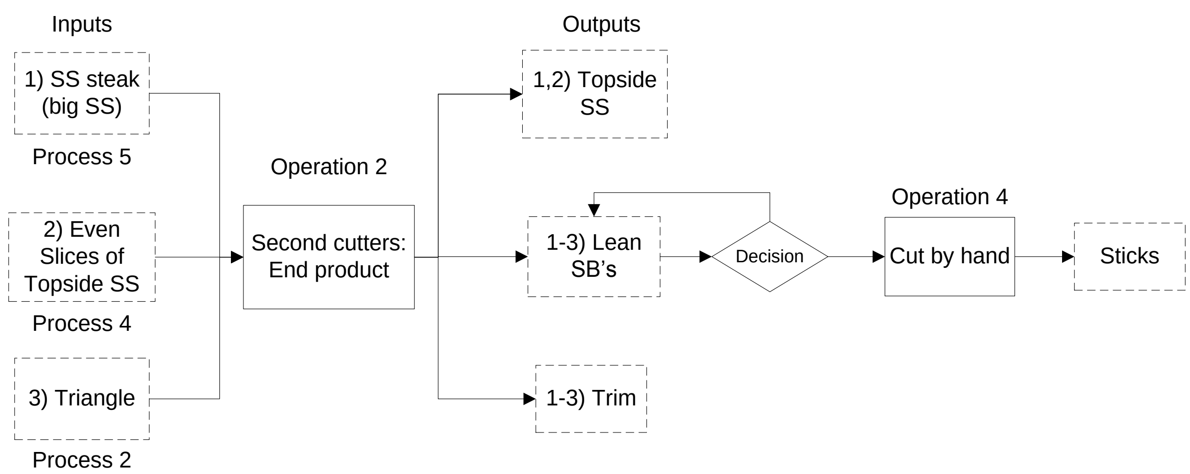


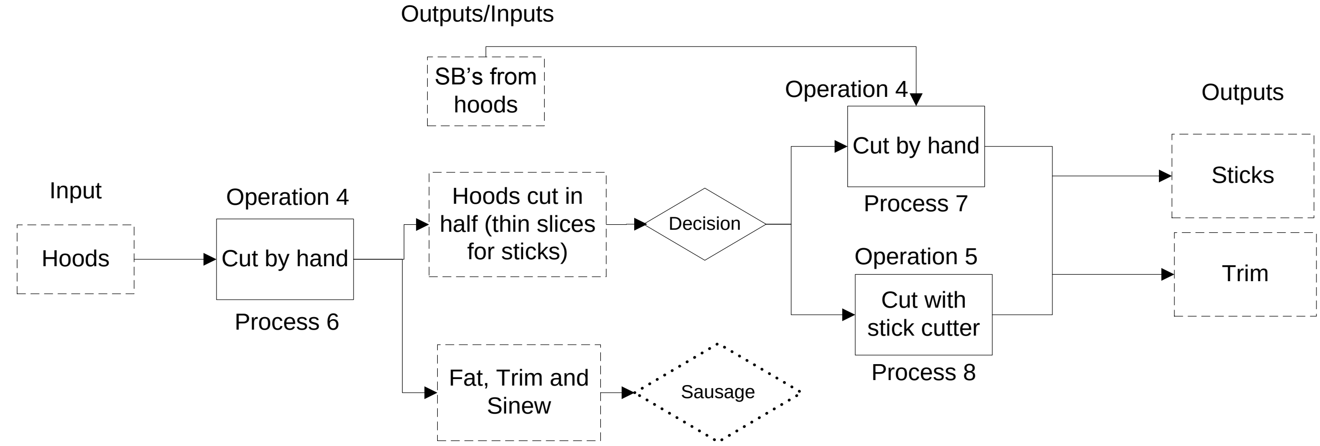


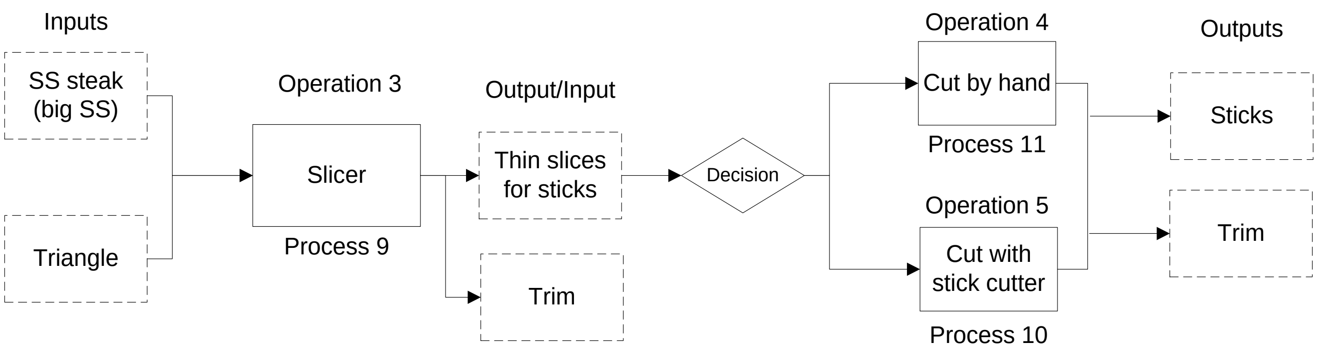
Topside


Sausage
Nuggets
Outputs
Hoods
Decision
SB's from hood
Decision
Sticks
Operation 3
Slicer
Input
Topsides
Operation 1
First Cutters: Clean Meat
Process 1
SS steak (big SS)
Decision
Triangle
Second cutters: End product
Operation 2
Trim
Fat

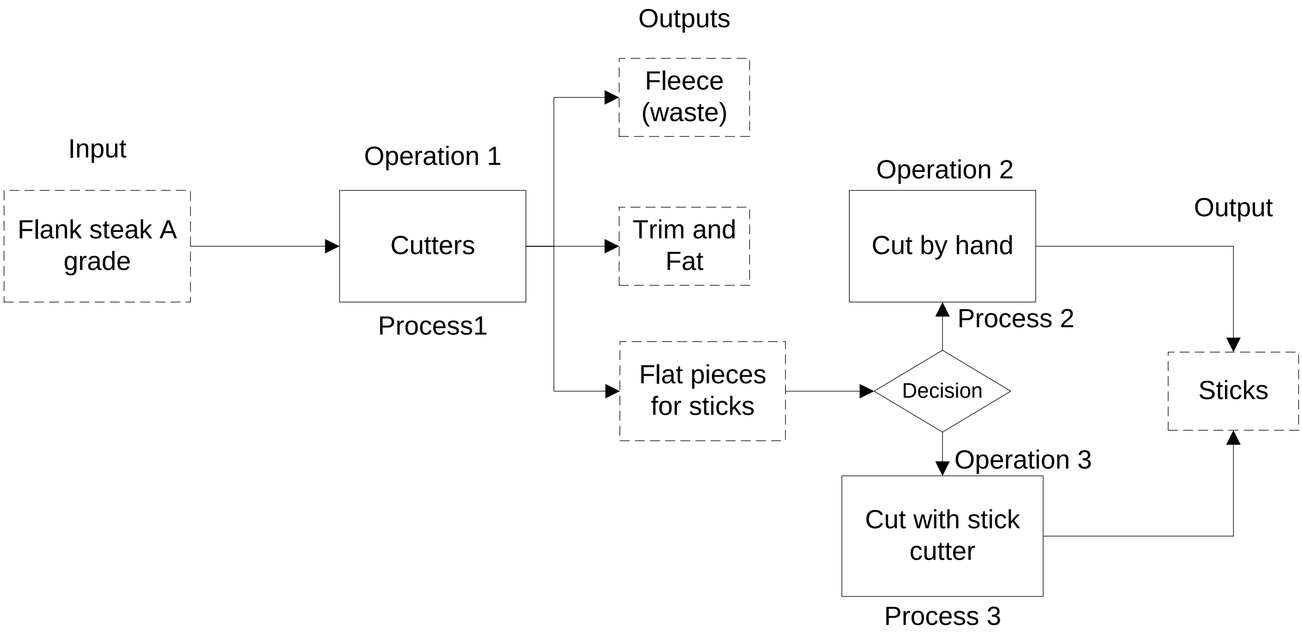

Outputs
Operation 2
Even Slices of SS
Second cutters: End product
Inputs
Operation 3
SS slices
Trim
SS steak (big SS)
Slicer
Decision
Process 4
Process 3
Sticks
Process 9-11


Inputs
Outputs
1) SS steak (big SS)
1,2) Topside SS
Process 5
Operation 2
Operation 4
2) Even Slices of Topside SS
Second cutters: End product
1-3) Lean SB's
Decision
Cut by hand
Sticks
Process 4
3) Triangle
1-3) Trim
Process 2


Outputs/Inputs
SB's from hoods
Operation 4
Cut by hand
Process 7
Outputs
Sticks
Input
Hoods
Operation 4
Cut by hand
Process 6
Hoods cut in half (thin slices for sticks)
Decision
Operation 5
Cut with stick cutter
Process 8
Trim
Fat, Trim and Sinew
Sausage


Inputs
SS steak (big SS)
Triangle
Operation 3
Slicer
Process 9
Output/Input
Thin slices for sticks
Trim
Decision
Operation 4
Cut by hand
Process 11
Operation 5
Cut with stick cutter
Process 10
Outputs
Sticks
Trim

Flank Steak


Outputs
Fleece (waste)
Input
Operation 1
Operation 2
Flank steak A grade
Cutters
Trim and Fat
Cut by hand
Output
Process1
Process 2
Flat pieces for sticks
Decision
Sticks
Operation 3
Cut with stick cutter
Process 3

Appendix D: Time Study Sheets

Silverside Flats

SS Flats	1	2	3	4	5
Supplier Name: **Country Meat**					
1) INPUT: Weight of 2 pieces SS Flats **kg**					
Time of 1 cutter **min:sec**					
Trim					
Fat					
Sinew					
Big SS					
Big Triangle					
total					
2) INPUT: Big Triangle to second cutter **kg**					
Time of 1 cutter **min:sec**					
Triangle SS					
SB's with Fat					
Trim					
total					
3) INPUT: Big SS to slicer **kg**					
Time of slicer **min:sec**					
Even slices of SS					
Trim					
total					
4) INPUT: Even slices SS to cutters **kg**					
Time of cutter **min:sec**					
SS					
SB's with fat					
Trim					
total					
5) INPUT: 2 Big SS to cutters **kg**					
Time of cutter **min:sec**					
SS					
SB's with fat					
Trim					
total					

Silverside A Grade

SS A grade	**1**	**2**	**3**	**4**	**5**
Supplier Name: **Beefmaster**					
1) INPUT: Weight of 1 piece SS A Grade **kg**					
Time of 1 cutter **min:sec**					
Trim					
Fat					
Sinew					
Big SS					
Big Triangle					
EYE					
Total					
2) INPUT: Big Triangle to second cutter **kg**					
Time of 1 cutter **min:sec**					
Triangle SS					
SB's with Fat					
Trim					
SB's Lean					
total					
3) INPUT: Eye to second cutter **kg**					
Time of 1 cutter **min:sec**					
SS EYE					
Fat					
Trim					
SB's lean					
SB's Fat					
total					
4) INPUT: Big SS to slicer **kg**					
Time of slicer **min:sec**					
Even slices of SS					
Trim					
totals					
5) INPUT: Even slices SS to cutters **kg**					
Time of cutter **min:sec**					
SS					
SB's with fat					
Trim					
total					

6) INPUT: 1 Big SS to cutters **kg**					
Time of cutter **min:sec**					
SS					
SB's with fat					
Fat					
Trim					
total					

Topside

Topside	**1**	**2**	**3**	**4**	**5**
Supplier Name:					
1) INPUT: Weight of 1 piece Topside **kg**					
Time of 1 cutter **min:sec**					
Trim					
Fat					
hoods					
Big SS					
Big Triangle					
SB's from hoods					
Loss					
total					
2) INPUT: Big Triangle to second cutter **kg**					
Time of 1 cutter **min:sec**					
Lean SB's					
Trim					
total					
3) INPUT: Big SS to slicer **kg**					
Time of slicer **min:sec**					
Even slices of Topside SS					
Trim					
total					
4) INPUT: Even slices SS to cutters **kg**					
Time of cutter **min:sec**					
Topside silverside					
Lean SB's					
Trim					
total					
5) INPUT: 1 Big SS for Topside SS					
cut by hand **kg**					
Time of cutter **min:sec**					
Topside SS					
Lean SB's					
Trim					
Total					

6) Hoods to cut in half **kg**					
Time of cutter **min:sec**					
Hoods cut in half					
Fat, Trim, Sinew for sausage					
Total					
7) INPUT: hoods cut in half to					
cut by hand **kg**					
Time of cutter **min:sec**					
Sticks					
Trim					
Total					
8) INPUT: hoods cut in half to					
stick cutter machine kg					
Time of stick machine **min:sec**					
Sticks					
Trim					
Total					
9) INPUT: Big SS and triangle to slicer **kg**					
Time of slicer **min:sec**					
Thin slices for sticks					
Trim					
Total					
10) INPUT: thin slices to					
stick cutter machine **kg**					
Time of stick machine **min:sec**					
finish sticks					
Trim					
Total					
11) INPUT: thin slices to cut by hand **kg**					
Time of cutter **min:sec**					
finish sticks					
Trim					
Total					

Flank Steak

A Grade Flank steak	**1**	**2**	**3**	**4**	**5**
Supplier Name:					
1) INPUT: 1 Flank steak **kg**					
Time of 1 cutter **min:sec**					
Trim and Fat					
Fleece (waste)					
Flat pieces for sticks					
total					
2) INPUT: Flat pieces for sticks to					
cut by hand **kg**					
Time of cutter **min:sec**					
Sticks					
total					
3) INPUT: Flat pieces for sticks to cut					
with stick cutter **kg**					
Time of stick cutter **min:sec**					
Sticks					
total					

Appendix E: Time Study Data

Silverside Flat

SS Flats	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1) INPUT: Weight of 2 pieces SS Flats **kg**	10.50	10.14	9.00	10.00	10.50	11.30	10.60	11.30	7.60	10.30	11.94	8.92	7.84	9.64	8.94
Time of 1 cutter **min:sec**	00:02:31	00:02:36	00:03:20	00:03:06	00:02:50	00:02:50	00:02:15	00:02:32	00:02:26	00:02:43	00:02:30	00:02:06	00:02:00	00:02:30	00:02:33
Time of 1 cutter **sec**	151	156	200	186	170	170	135	152	146	163	150	146	120	150	153
Trim	1.70	1.60	1.50	1.60	1.70	1.66	1.66	2.28	1.56	2.02	2.26	1.66	1.64	1.90	1.66
Fat	0.10	0.10	0.10	0.30	0.10	0.76	0.30	0.68	0.22	0.32	0.28	0.26	0.12	0.22	0.22
Sinew	0.10	0.10	0.10	0.10	0.10	0.14	0.14	0.14	0.08	0.10	0.16	0.12	0.12	0.14	0.10
Big SS	6.90	6.20	5.40	5.80	6.20	6.50	6.54	6.30	4.70	6.00	7.42	5.52	5.02	6.08	5.68
Big Triangle	1.60	2.00	1.60	1.70	2.00	1.90	1.94	1.82	1.00	1.60	1.90	1.38	1.00	1.32	1.30
total	**10.40**	**10.00**	**8.70**	**9.50**	**10.10**	**10.96**	**10.58**	**11.22**	**7.56**	**10.04**	**12.02**	**8.94**	**7.90**	**9.66**	**8.96**
2) INPUT: Big Triangle to second cutter **kg**	1.60	2.00	1.60	1.70	2.00	1.90	1.94	1.82	1.00	1.60	1.90	1.38	1.00	1.32	1.30
Time of 1 cutter **min:sec**	00:00:23	00:00:17	00:00:16	00:00:15	00:00:21	00:00:21	00:00:21	00:00:25	00:00:10	00:00:13	00:00:14	00:00:14	00:00:13	00:00:17	00:00:19
Time of 1 cutter **sec**	23	17	16	15	21	21	21	25	10	13	14	14	13	17	19
Triangle SS	0.76	0.94	0.80	0.78	0.80	0.88	0.86	0.48	0.38	0.80	0.88	0.64	0.58	0.62	0.68
SB's with Fat	0.92	1.14	0.90	1.00	1.26	1.00	1.06	1.34	0.64	0.82	1.00	0.72	0.40	0.68	0.62
Trim						0.04									
total	**1.68**	**2.08**	**1.70**	**1.78**	**2.06**	**1.92**	**1.92**	**1.82**	**1.02**	**1.62**	**1.88**	**1.36**	**0.98**	**1.30**	**1.30**
3) INPUT: Big SS to slicer **kg**	6.90	6.20	5.40	5.80	6.20	6.50	6.54	6.30	4.70	6.00	7.42	5.52	5.02	6.08	5.68
Time of slicer **min:sec**	00:00:39	00:00:26	00:00:40	00:00:38	00:00:35	00:00:28	00:00:29	00:00:26	00:00:26	00:00:32	00:00:32	00:00:25	00:00:30	00:00:26	00:00:24
Time of slicer **sec**	39	26	40	38	35	28	29	26	26	32	32	25	30	26	24
Even slices of SS	6.28	5.60	5.04	4.96	5.24	6.02	5.96	5.54	4.18	5.90	7.04	5.04	4.62	5.70	5.00
Trim	0.58	0.34	0.56	0.94	0.82	0.50	0.58	0.76	0.52	0.12	0.34	0.48	0.40	0.42	0.66
total	**6.86**	**5.94**	**5.60**	**5.90**	**6.06**	**6.52**	**6.54**	**6.30**	**4.70**	**6.02**	**7.38**	**5.52**	**5.02**	**6.12**	**5.66**
4) INPUT: Even slices SS to cutters **kg**	6.28	5.60	5.04	4.96	5.24	6.02	5.96	5.54	4.18	5.90	7.04	5.04	4.62	5.70	5.00
Time of cutter **min:sec**	00:01:18	00:00:55	00:01:08	00:00:50	00:01:03	00:00:44	00:00:59	00:00:41	00:00:46	00:00:53	00:00:38	00:00:28	00:00:27	00:00:29	00:00:29
Time of cutter **sec**	78	55	68	50	63	44	59	41	46	53	38	28	27	29	29
SS	5.72	5.64	4.74	4.40	5.26	5.80	5.48	5.26	3.94	5.40	6.76	4.92	4.34	5.10	4.86
SB's with fat	0.48			0.32										0.44	
Trim	0.20	0.16	0.24	0.22	0.18	0.22	0.48	0.26	0.28	0.50	0.28	0.12	0.28	0.16	0.14
total	**6.40**	**5.80**	**4.98**	**4.94**	**5.44**	**6.02**	**5.96**	**5.52**	**4.22**	**5.90**	**7.04**	**5.04**	**4.62**	**5.70**	**5.00**
5) INPUT: 2 Big SS to cutters **kg**	7.40	6.20	7.40	7.20	6.80	7.36	5.68	5.62	5.52	5.76	7.80	7.40	7.26	7.32	5.02
Time of cutter **min:sec**	00:01:26	00:01:02	00:01:06	00:01:10	00:01:08	00:01:05	00:00:50	00:00:44	00:01:00	00:00:57	00:01:32	00:01:07	00:01:33	00:01:18	00:01:05
Time of cutter **sec**	86	62	66	70	68	65	50	44	60	57	92	67	93	78	65
SS	6.66	5.56	6.80	6.30	6.00	6.82	4.98	4.94	4.60	4.84	6.80	6.75	6.42	6.62	4.34
SB's with fat	0.48	0.42	0.44	0.54	0.60	0.40	0.56	0.68	0.72	0.72	0.18	0.14	0.66	0.58	0.42
Trim	0.24	0.10	0.06	0.28	0.12	0.14	0.14		0.18	0.18	0.78	0.48	0.18	0.14	0.28
total	**7.38**	**6.08**	**7.30**	**7.12**	**6.72**	**7.36**	**5.68**	**5.62**	**5.50**	**5.74**	**7.76**	**7.37**	**7.26**	**7.34**	**5.04**

SS Flats	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1) INPUT: Weight of 2 pieces SS Flats **kg**	10.38	10.72	10.78	11.40	9.80	14.00	11.72	11.74	11.06	10.18	8.14	13.68	8.98	7.28	7.80
Time of 1 cutter **min:sec**	00:02:03	00:02:01	00:02:11	00:02:11	00:02:34	00:02:49	00:02:43	00:02:46	00:02:15	00:02:40	00:01:52	00:02:07	00:01:53	00:01:46	00:02:02
Time of 1 cutter **sec**	123	121	131	131	154	169	163	166	135	160	112	127	113	106	122
Trim	1.30	1.48	1.46	1.54	1.08	2.46	2.10	2.04	1.92	1.74	1.76	2.50	1.86	1.40	1.70
Fat	0.20	0.14	0.12	0.20	0.26	0.32	0.20	0.22	0.22	0.36	0.44	0.60	0.32	0.24	0.28
Sinew	0.14	0.12	0.22	0.18	0.14	0.18	0.12	0.12	0.12	0.14	0.10	0.14	0.10	0.08	0.10
Big SS	6.66	6.80	6.88	7.26	6.38	8.28	7.12	6.96	6.68	6.22	4.58	8.00	5.10	4.26	4.36
Big Triangle	2.08	2.18	2.10	2.24	1.96	2.70	2.14	2.38	2.08	1.68	1.24	2.42	1.62	1.24	1.38
total	**10.38**	**10.72**	**10.78**	**11.42**	**9.82**	**13.94**	**11.68**	**11.72**	**11.02**	**10.14**	**8.12**	**13.66**	**9.00**	**7.22**	**7.82**
2) INPUT: Big Triangle to second cutter **kg**	2.08	2.18	2.10	2.24	1.96	2.70	2.14	2.38	2.08	1.68	1.30	2.50	1.70	1.30	1.40
Time of 1 cutter **min:sec**	00:00:20	00:00:28	00:00:26	00:00:29	00:00:32	00:00:18	00:00:15	00:00:15	00:00:16	00:00:11	00:00:08	00:00:16	00:00:15	00:00:15	00:00:16
Time of 1 cutter **sec**	20	28	26	29	32	18	15	15	16	11	8	16	15	15	16
Triangle SS	0.94	0.90	0.88	1.00	0.86	1.56	0.92	0.92	0.88	0.80	0.70	1.00	0.90	0.60	0.70
SB's with Fat	1.14	1.16	1.20	1.20	1.00	1.14	1.20	1.44	1.20	0.88	0.60	1.50	0.80	0.70	0.70
Trim		0.10			0.06										
total	**2.08**	**2.16**	**2.08**	**2.20**	**1.92**	**2.70**	**2.12**	**2.36**	**2.08**	**1.68**	**1.30**	**2.50**	**1.70**	**1.30**	**1.40**
3) INPUT: Big SS to slicer **kg**	6.66	6.80	6.88	7.26	6.38	8.28	7.12	6.96	6.68	6.22	4.58	8.00	5.10	4.26	4.36
Time of slicer **min:sec**	00:00:25	00:00:33	00:00:33	00:00:27	00:00:27	00:00:37	00:00:33	00:00:32	00:00:32	00:00:22	00:00:22	00:00:28	00:00:20	00:00:23	00:00:24
Time of slicer **sec**	25	33	33	27	27	37	33	32	32	22	22	28	20	23	24
Even slices of SS	6.48	6.66	6.56	6.68	6.04	7.92	6.54	6.84	6.52	5.98	4.24	7.58	4.74	4.10	4.08
Trim		0.30	0.30	0.58	0.32	0.34	0.58	0.10	0.18	0.28	0.30	0.40	0.30	0.14	0.20
total	**6.48**	**6.96**	**6.86**	**7.26**	**6.36**	**8.26**	**7.12**	**6.94**	**6.70**	**6.26**	**4.54**	**7.98**	**5.04**	**4.24**	**4.28**
4) INPUT: Even slices SS to cutters **kg**	6.48	6.66	6.56	6.68	5.88	7.92	6.54	6.84	6.52	5.98	4.24	7.58	4.74	4.10	4.08
Time of cutter **min:sec**	00:00:34	00:00:56	00:00:56	00:00:48	00:00:36	00:00:47	00:00:35	00:00:37	00:00:47	00:00:27	00:00:28	00:00:31	00:00:32	00:00:28	00:00:31
Time of cutter **sec**	34	56	56	48	36	47	35	37	47	27	28	31	32	28	31
SS	5.88	6.22	5.80	6.30	5.70	7.60	6.28	6.64	5.62	5.76	4.04	7.38	4.10	3.54	3.60
SB's with fat	0.32								0.42				0.38	0.38	0.30
Trim	0.26	0.44	0.76	0.38	0.16	0.34	0.26	0.20	0.48	0.20	0.20	0.18	0.26	0.16	0.16
total	**6.46**	**6.66**	**6.56**	**6.68**	**5.86**	**7.94**	**6.54**	**6.84**	**6.52**	**5.96**	**4.24**	**7.56**	**4.74**	**4.08**	**4.06**
5) INPUT: 2 Big SS to cutters **kg**	6.14	8.88	7.20	5.22	5.62	5.32	5.94	6.26	6.10	5.16	6.18	6.84	5.42	7.28	5.18
Time of cutter **min:sec**	00:01:14	00:01:42	00:01:11	00:01:12	00:01:00	00:00:44	00:00:51	00:00:53	00:01:05	00:00:53	00:01:04	00:01:07	00:01:08	00:01:12	00:00:59
Time of cutter **sec**	74	102	71	72	60	44	51	53	65	53	64	67	68	72	59
SS	5.38	8.04	6.60	4.32	4.66	5.14	5.10	5.40	5.62	4.42	5.74	6.04	4.46	6.98	4.38
SB's with fat	0.22	0.14	0.20	0.56	0.64		0.60	0.78	0.16	0.44		0.38	0.54		0.34
Trim	0.54	0.70	0.40	0.24	0.34	0.14	0.22	0.10	0.30	0.30	0.44	0.40	0.40	0.30	0.46
total	**6.14**	**8.88**	**7.20**	**5.12**	**5.64**	**5.28**	**5.92**	**6.28**	**6.08**	**5.16**	**6.18**	**6.82**	**5.40**	**7.28**	**5.18**

Silverside A grade

SS A grade	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1) INPUT: Weight of 1 piece SS A Grade **kg**	7.56	7.99	7.9	8.55	8.53	7.84	8.42	5.66	7.58	7.32	6.2	8.72	5.3	10.1	11.14	8.92	8.52	8.52	7.76	7.58	11.02	10.52	9.6	7.22	9.46	10.28	10.66	8.8	11.24	9.7
Time of 1 cutter **min:sec**	00:01:46	00:01:52	00:01:57	00:02:15	00:02:08	00:01:52	00:01:53	00:01:50	00:02:03	00:02:25	00:01:30	00:01:54	00:01:44	00:01:59	00:02:18	00:01:42	00:01:51	00:01:49	00:01:42	00:02:12	00:02:19	00:01:57	00:02:05	00:01:52	00:02:00	00:03:26	00:03:03	00:03:03	00:03:38	00:03:04
Time of 1 cutter **sec**	106	112	117	135	128	112	113	110	123	145	90	114	104	119	138	102	111	109	102	132	139	117	125	112	120	206	183	183	218	184
Trim	1.4	1.39	1.45	1.56	1.58	1.26	1.34	0.98	1.38	1.5	1.36	1.62	1.3	2.06	2.48	1.66	1.68	1.66	1.42	1.12	1.78	1.54	1.8	1.18	1.64	1.64	1.54	1.52	1.78	1.4
Fat	0.22	0.17	0.2	0.61	0.45	0.18	0.1	0.1	0.12	0.3	0.1	0.18	0.08	0.4	0.46	0.3	0.18	0.28	0.36	0.26	0.26	0.32	0.18	0.32	0.16	0.16	0.36	0.24	0.56	0.34
Sinew	0.06	0.06	0.07	0.07	0.07	0.08	0.06	0.04	0.08	0.06	0.06	0.08	0.04	0.08	0.12	0.06	0.08	0.06	0.06	0.06	0.08	0.08	0.06	0.06	0.08	0.12	0.06	0.06	0.1	0.06
Big SS	3.16	3.36	3.05	3.45	3.63	3.06	3.5	2.5	3.06	2.44	2.62	3.48	2	4.38	4.34	3.38	3.1	3.28	2.9	2.96	4.46	4.36	4	3.18	3.96	4.46	4.5	3.46	4.42	4.28
Big Triangle	0.84	0.91	1.01	0.87	0.78	1.12	1.02	0.58	0.86	0.96	0.72	1.08	0.68	0.94	1.06	1.1	1.08	1	0.98	1.06	1.43	1.26	1.06	0.74	1.2	1.26	1.24	0.82	1.26	1.1
EYE	1.85	2.09	2.1	1.98	2.01	2.08	2.32	1.44	2.06	2.04	1.32	2.26	1.2	2.24	2.66	2.42	2.4	2.2	2.04	2.12	3.02	3	2.5	1.72	2.4	2.64	2.94	2.66	3.08	2.52
Total	**7.53**	**7.98**	**7.88**	**8.54**	**8.52**	**7.78**	**8.34**	**5.64**	**7.56**	**7.3**	**6.18**	**8.7**	**5.3**	**10.1**	**11.12**	**8.92**	**8.52**	**8.48**	**7.76**	**7.58**	**11.03**	**10.56**	**9.6**	**7.2**	**9.44**	**10.28**	**10.64**	**8.76**	**11.2**	**9.7**
2) INPUT: Big Triangle to second cutter **kg**	0.84	0.91	1.01	0.87	0.78	1.12	1.02	0.58	0.86	0.96	0.72	1.08	0.68	0.94	1.06	1.1	1.08	1	0.98	1.06	1.43	1.26	1.06	0.74	1.2	1.26	1.24	0.82	1.26	1.1
Time of 1 cutter **min:sec**	00:00:09	00:00:09	00:00:10	00:00:08	00:00:05	00:00:11	00:00:13	00:00:06	00:00:12	00:00:09	00:00:11	00:00:16	00:00:09	00:00:12	00:00:15	00:00:16	00:00:13	00:00:14	00:00:09	00:00:14	00:00:11	00:00:15	00:00:12	00:00:06	00:00:14	00:00:13	00:00:21	00:00:09	00:00:18	00:00:09
Time of 1 cutter **sec**	9	9	10	8	5	11	13	6	12	9	11	16	9	12	15	16	13	14	9	14	11	15	12	6	14	13	21	9	18	9
Triangle SS	0.4	0.41	0.42	0.41	0.38	0.44	0.42		0.36	0.38	0.34	0.46	0.3	0.4	0.44	0.44	0.44	0.42	0.46	0.38	0.54	0.46	0.44	0.34	0.48	0.48	0.5	0.38	0.54	0.46
SB's with Fat	0.44	0.51	0.59	0.46	0.39	0.66	0.6	0.6	0.52	0.56	0.38	0.62	0.36	0.54	0.64	0.8	0.64	0.6	0.52	0.68	0.86	0.78	0.62	0.4	0.7				0.42	0.64
Trim																										0.1	0.02			
SB's Lean																										0.66	0.72	0.44	0.3	
total	**0.84**	**0.92**	**1.01**	**0.87**	**0.77**	**1.1**	**1.02**	**0.6**	**0.88**	**0.94**	**0.72**	**1.08**	**0.66**	**0.94**	**1.08**	**1.24**	**1.08**	**1.02**	**0.98**	**1.06**	**1.4**	**1.24**	**1.06**	**0.74**	**1.18**	**1.24**	**1.24**	**0.82**	**1.26**	**1.1**
3) INPUT: Eye to second cutter **kg**	1.85	2.09	2.1	1.98	2.01	2.08	2.32	1.44	2.06	2.04	1.32	2.26	1.2	2.24	2.66	2.42	2.4	2.2	2.04	2.12	3.02	3	2.5	1.72	2.4	2.64	2.94	2.66	3.08	2.52
Time of 1 cutter **min:sec**	00:00:19	00:00:21	00:00:19	00:00:22	00:00:23	00:00:26	00:00:23	00:00:21	00:00:22	00:00:26	00:00:19	00:00:23	00:00:20	00:00:21	00:00:35	00:00:36	00:00:28	00:00:25	00:00:24	00:00:26	00:00:33	00:00:32	00:00:24	00:00:21	00:00:25	00:00:38	00:00:37	00:00:44	00:00:46	00:00:33
Time of 1 cutter **sec**	19	21	19	22	23	26	23	21	22	26	19	23	20	21	35	36	28	25	24	26	33	32	24	21	25	38	37	44	46	33
SS EYE	1.6	1.8	1.75	1.7	1.52	1.56	1.94	0.96	1.72	1.74	1.1	2	1	1.92	2.18	1.8	1.94	1.88	1.7	1.72	2.66	2.46	2.08	1.16	2.12	2.16	2.18	2	2.28	2.04
Fat					0.08		0.1			0.06					0.08															
Trim		0.01	0.05	0.02	0.13	0.12			0.04		0.04		0.02		0.02			0.06	0.12	0.1	0.02	0.18	0.01	0.04	0.04	0.16		0.08	0.18	0.18
SB's lean	0.23	0.28	0.29	0.25	0.28	0.38	0.3	0.46	0.28	0.24	0.18	0.26	0.16	0.28	0.36	0.48	0.24	0.28	0.22	0.28	0.3	0.34	0.38	0.16	0.24	0.3	0.56	0.34	0.48	0.3
SB's Fat																0.12	0.22							0.34			0.2	0.22	0.16	
total	**1.83**	**2.09**	**2.09**	**1.97**	**2.01**	**2.06**	**2.34**	**1.42**	**2.04**	**2.04**	**1.32**	**2.26**	**1.18**	**2.2**	**2.64**	**2.4**	**2.4**	**2.22**	**2.04**	**2.1**	**2.98**	**2.98**	**2.47**	**1.7**	**2.4**	**2.62**	**2.94**	**2.64**	**3.1**	**2.52**
4) INPUT: Big SS to slicer **kg**	3.16	3.36	3.05	3.45	3.63	3.06	3.5	2.5	3.06	2.44	2.62	3.48	2	4.38	4.34	3.38	3.1	3.28	2.9	2.96	4.46	4.36	4	3.18	3.96	4.46	4.5	3.46	4.42	4.28
Time of slicer **min:sec**	00:00:12	00:00:16	00:00:16	00:00:17	00:00:14	00:00:10	00:00:11	00:00:11	00:00:10	00:00:09	00:00:12	00:00:12	00:00:10	00:00:19	00:00:19	00:00:13	00:00:11	00:00:12	00:00:13	00:00:11	00:00:19	00:00:16	00:00:15	00:00:11	00:00:11	00:00:08	00:00:11	00:00:10	00:00:10	00:00:14
Time of slicer **sec**	12	16	16	17	14	10	11	11	10	9	12	12	10	19	19	13	11	12	13	11	19	16	15	11	11	8	11	10	10	14
Even slices of SS	2.85	3.08	2.82	3.08	3.25	2.66	3.5	2.3	2.64	2.24	2.48	3.46	1.92	3.94	4.18	2.98	2.84	2.88	2.72	2.72	4.02	4.08	3.68	2.74	3.76	4.04	4.16	3.34	4.1	3.98
Trim	0.31	0.28	0.23	0.36	0.38	0.4		0.2	0.42	0.18	0.16	0.02	0.08	0.44	0.16	0.42	0.26	0.4	0.18	0.24	0.4	0.26	0.28	0.42	0.18	0.42	0.32	0.1	0.32	0.3
totals	**3.16**	**3.36**	**3.05**	**3.44**	**3.63**	**3.06**	**3.5**	**2.5**	**3.06**	**2.42**	**2.64**	**3.48**	**2**	**4.38**	**4.34**	**3.4**	**3.1**	**3.28**	**2.9**	**2.96**	**4.42**	**4.34**	**3.96**	**3.16**	**3.94**	**4.46**	**4.48**	**3.44**	**4.42**	**4.28**
5) INPUT: Even slices SS to cutters **kg**	2.85	3.08	2.82	3.08	3.25	2.66	3.5	2.3	2.64	2.24	2.48	3.46	1.92	3.94	4.18	2.98	2.84	2.88	2.72	2.72	4.02	4.08	3.68	2.74	3.76	4.04	4.16	3.34	4.1	3.98
Time of cutter **min:sec**	00:00:21	00:00:20	00:00:19	00:00:18	00:00:19	00:00:28	00:00:30	00:00:23	00:00:19	00:00:29	00:00:20	00:00:30	00:00:15	00:00:25	00:00:34	00:00:17	00:00:19	00:00:18	00:00:18	00:00:16	00:00:34	00:00:33	00:00:28	00:00:14	00:00:21	00:00:32	00:00:32	00:00:22	00:00:29	00:00:23
Time of cutter **sec**	21	20	19	18	19	28	30	23	19	29	20	30	15	25	34	17	19	18	18	16	34	33	28	14	21	32	32	22	29	23
SS	2.66	2.89	2.69	2.94	3.1	2.4	3.3	2.06	2.44	2.06	2.34	2.9	1.5	3.72	3.94	2.86	2.62	2.68	2.5	2.4	3.76	3.8	3.46	2.64	3.6	3.78	3.82	3.16	3.72	3.68
SB's with fat												0.38	0.36																	
Trim	0.19	0.19	0.13	0.14	0.14	0.26	0.2	0.24	0.2	0.18	0.14	0.18	0.08	0.22	0.24	0.12	0.22	0.2	0.22	0.32	0.24	0.26	0.22	0.1	0.16	0.26	0.34	0.18	0.38	0.3
total	**2.85**	**3.08**	**2.82**	**3.08**	**3.24**	**2.66**	**3.5**	**2.3**	**2.64**	**2.24**	**2.48**	**3.46**	**1.94**	**3.94**	**4.18**	**2.98**	**2.84**	**2.88**	**2.72**	**2.72**	**4**	**4.06**	**3.68**	**2.74**	**3.76**	**4.04**	**4.16**	**3.34**	**4.1**	**3.98**
Supplier Name: SPARTA																														
6) INPUT: 1 Big SS to cutters **kg**	3.24	3.78	3.14	4.32	2.68	4.12	4.14	4.16	4.30	4.46	3.24	3.48	3.48	3.26	4.42	3.74	3.48	4.86	4.12	3.66	3.36	3.80	2.96	3.64	3.90	3.78	3.24	3.50	3.74	2.40
Time of cutter **min:sec**	00:01:20	00:01:17	00:01:00	00:01:39	00:01:02	00:01:30	00:01:42	00:01:23	00:01:13	00:01:13	00:00:35	00:00:51	00:00:52	00:00:36	00:00:50	00:00:58	00:00:51	00:00:53	00:00:50	00:00:58	00:00:47	00:00:56	00:00:33	00:00:40	00:00:43	00:00:39	00:00:34	00:00:38	00:00:50	00:00:33
Time of cutter **sec**	80	77	60	99	62	90	102	83	73	73	35	51	52	36	50	58	51	53	50	58	47	56	33	40	43	39	34	38	50	33
SS	2.78	3.38	2.80	3.80	2.18	3.60	3.62	3.86	3.80	4.04	2.72	2.88	3.06	2.92	4.02	3.32	2.92	4.48	3.66	2.90	2.56	3.34	2.36	3.24	3.66	3.34	2.54	3.12	3.26	1.88
SB's with fat	0.30	0.14		0.28	0.30	0.22	0.16		0.22		0.40	0.34					0.34	0.16	0.16	0.42	0.40		0.30				0.38			0.16
Fat																														
Trim	0.16	0.26	0.34	0.24	0.20	0.28	0.36	0.26	0.28	0.40	0.12	0.26	0.42	0.32	0.38	0.42	0.22	0.22	0.30	0.36	0.40	0.42	0.30	0.38	0.22	0.30	0.30	0.38	0.48	0.34
total	**3.24**	**3.78**	**3.14**	**4.32**	**2.68**	**4.10**	**4.14**	**4.12**	**4.30**	**4.44**	**3.24**	**3.48**	**3.48**	**3.24**	**4.40**	**3.74**	**3.48**	**4.86**	**4.12**	**3.68**	**3.36**	**3.76**	**2.96**	**3.62**	**3.88**	**3.64**	**3.22**	**3.50**	**3.74**	**2.38**

Topside

Topside	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
1) INPUT: Weight of 1 pieces Topside **kg**	10.42	8.82	9.94	10.54	6.02	9.76	6.80	10.60	6.04	8.56	8.44	10.42	8.24	8.42	5.14
Time of 1 cutter **min:sec**	00:03:52	00:03:52	00:04:25	00:03:58	00:03:17	00:03:38	00:02:39	00:03:51	00:03:01	00:02:58	00:02:29	00:03:18	00:02:53	00:02:39	00:02:23
Time of 1 cutter **sec**	232	232	265	238	197	218	159	231	181	178	149	198	173	159	143
Trim	1.94	1.64	1.60	1.44	0.98	1.72	1.34	2.00	0.58	1.88	2.24	2.32	1.94	1.58	1.30
Fat	0.36	0.84	0.86	1.26	0.52	1.48	1.12	0.80	1.26	0.42	0.80	1.74	0.62	1.70	0.40
hoods	1.36	1.06	1.44	1.34	0.66	0.64	0.46	0.70	0.36	0.70	0.50	0.70	0.76	0.66	0.32
Big SS	4.58	3.84	4.20	4.58	2.76	4.16	2.70	5.06	2.74	4.08	3.48	3.78	3.50	3.02	2.10
Big Triangle	1.74	1.00	1.46	1.44	0.84	1.30	0.92	1.32	0.78	1.08	1.12	1.38	1.02	1.08	0.82
SB's from hoods	0.42	0.38	0.38	0.48	0.26	0.46	0.28	0.70	0.28	0.42	0.28	0.48	0.40	0.36	0.20
total	**10.40**	**8.76**	**9.94**	**10.54**	**6.02**	**9.76**	**6.82**	**10.58**	**6.00**	**8.58**	**8.42**	**10.40**	**8.24**	**8.40**	**5.14**
2) INPUT: Big Triangle to second cutter **kg**	1.74	1.00	1.46	1.44	0.84	1.30	0.92	1.32	0.78	1.08	1.12	1.38	1.02	1.08	0.82
Time of 1 cutter **min:sec**	00:00:19	00:00:08	00:00:18	00:00:13	00:00:12	00:00:12	00:00:10	00:00:11	00:00:10	00:00:16	00:00:10	00:00:18	00:00:09	00:00:12	00:00:09
Time of 1 cutter **sec**	19	8	18	13	12	12	10	11	10	16	10	18	9	12	9
Lean SB's	1.74	1.00	1.46	1.44	0.84	1.22	0.90	1.32	0.78	1.08	1.12	1.36	1.02	1.08	0.82
Trim						0.08							0.02		
total	**1.74**	**1.00**	**1.46**	**1.44**	**0.84**	**1.30**	**0.90**	**1.32**	**0.78**	**1.08**	**1.12**	**1.36**	**1.04**	**1.08**	**0.82**
3) INPUT: Big SS to slicer **kg**	4.58	3.84	4.20	4.58	2.76	4.16	2.70	5.06	2.74	4.08	3.48	3.78	3.50	3.02	2.10
Time of slicer **min:sec**	00:00:11	00:00:11	00:00:12	00:00:16	00:00:13	00:00:16	00:00:11	00:00:20	00:00:11	00:00:23	00:00:12	00:00:13	00:00:12	00:00:12	00:00:09
Time of slicer **sec**	11	11	12	16	13	16	11	20	11	23	12	13	12	12	9
Even slices of Topside SS	4.46	3.58	3.86	4.08	2.54	3.80	2.52	4.80	2.46	3.86	3.36	3.66	3.42	2.96	1.86
Trim	0.10	0.26	0.32	0.48	0.20	0.30	0.16	0.24	0.28	0.18	0.12	0.12	0.08	0.06	0.24
total	**4.56**	**3.84**	**4.18**	**4.56**	**2.74**	**4.10**	**2.68**	**5.04**	**2.74**	**4.04**	**3.48**	**3.78**	**3.50**	**3.02**	**2.10**
4) INPUT: Even slices SS to cutters **kg**	4.46	3.58	3.86	4.08	2.54	3.80	2.52	4.80	2.46	3.86	3.36	3.66	3.42	2.96	1.86
Time of cutter **min:sec**	00:00:38	00:00:29	00:00:27	00:00:30	00:00:22	00:00:31	00:00:22	00:00:40	00:00:24	00:00:28	00:00:30	00:00:33	00:00:34	00:00:42	00:00:30
Time of cutter **sec**	38	29	27	30	22	31	22	40	24	28	30	33	34	42	30
Topside silverside	3.76	3.38	3.72	3.86	2.42	3.62	1.94	4.56	2.36	3.74	3.12	3.52	3.18	2.42	1.68
Lean SB's	0.40						0.44							0.40	
Trim	0.28	0.20	0.14	0.22	0.12	0.18	0.14	0.24	0.08	0.12	0.22	0.14	0.24	0.14	0.14
total	**4.44**	**3.58**	**3.86**	**4.08**	**2.54**	**3.80**	**2.52**	**4.80**	**2.44**	**3.86**	**3.34**	**3.66**	**3.42**	**2.96**	**1.82**
5) INPUT: 1 Big SS for Topside SS	2.48	3.24	4.50	2.36	4.78	2.14	2.58	2.70	3.72	2.56	2.86	3.10	3.10	3.60	2.42
cut by hand **kg**															
Time of cutter **min:sec**	00:00:15	00:00:32	00:00:28	00:00:30	00:00:47	00:00:16	00:00:14	00:00:19	00:00:28	00:00:26	00:00:24	00:00:15	00:00:20	00:00:24	00:00:22
Time of cutter **sec**	15	32	28	30	47	16	14	19	28	26	24	15	20	24	22
Topside SS	2.04	2.78	4.16	2.00	4.54	1.78	2.42	2.42	3.52	1.90	2.28	2.90	2.78	3.20	1.80
Lean SB's	0.42	0.40	0.36	0.36	0.18	0.34	0.16	0.28	0.20	0.66	0.60	0.18	0.32	0.42	0.62
Trim		0.06		0.02	0.08							0.02			
Total	**2.46**	**3.24**	**4.52**	**2.38**	**4.80**	**2.12**	**2.58**	**2.70**	**3.72**	**2.56**	**2.88**	**3.10**	**3.10**	**3.62**	**2.42**

Topside	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
1) INPUT: Weight of 1 pieces Topside **kg**	7.22	8.92	5.24	8.38	8.76	7.72	8.96	7.56	9.72	11.06	7.92	7.16	9.30	7.78	5.04
Time of 1 cutter **min:sec**	00:04:13	00:04:06	00:03:35	00:04:08	00:04:07	00:03:34	00:03:48	00:03:35	00:03:20	00:03:37	00:02:12	00:01:50	00:02:36	00:01:51	00:02:00
Time of 1 cutter **sec**	253	246	215	248	247	214	228	215	200	217	132	110	156	111	120
Trim	1.62	1.70	0.88	1.76	1.72	1.28	1.52	1.30	1.34	1.86	1.36	1.48	1.94	1.92	1.38
Fat	0.66	0.98	0.90	1.08	0.42	1.30	0.76	0.60	0.92	1.10	1.60	1.24	1.22	1.02	0.42
hoods	0.54	0.68	0.32	0.56	0.66	0.94	1.20	0.92	1.18	1.38	0.46	0.38	0.58	0.52	0.44
Big SS	2.94	3.78	2.12	3.70	4.22	3.00	4.06	3.38	4.42	4.98	3.10	2.70	4.02	2.82	1.92
Big Triangle	1.02	1.24	0.76	0.92	1.20	0.94	1.08	0.98	1.46	1.40	1.00	1.04	1.14	1.04	0.64
SB's from hoods	0.42	0.54	0.28	0.36	0.54	0.22	0.34	0.36	0.40	0.34	0.40	0.28	0.40	0.42	0.18
total	**7.20**	**8.92**	**5.26**	**8.38**	**8.76**	**7.68**	**8.96**	**7.54**	**9.72**	**11.06**	**7.92**	**7.12**	**9.30**	**7.74**	**4.98**
2) INPUT: Big Triangle to second cutter **kg**	1.02	1.24	0.76	0.92	1.20	0.94	1.08	0.98	1.46	1.40	1.00	1.04	1.14	1.04	0.64
Time of 1 cutter **min:sec**	00:00:13	00:00:10	00:00:09	00:00:08	00:00:14	00:00:07	00:00:06	00:00:07	00:00:12	00:00:10	00:00:06	00:00:12	00:00:08	00:00:07	00:00:07
Time of 1 cutter **sec**	13	10	9	8	14	7	6	7	12	10	6	12	8	7	7
Lean SB's	0.98	1.24	0.74	0.92	1.08	0.96	1.08	0.98	1.46	1.40	0.96	1.06	1.12	1.04	0.64
Trim	0.04		0.02		0.14						0.02		0.01		
total	**1.02**	**1.24**	**0.76**	**0.92**	**1.22**	**0.96**	**1.08**	**0.98**	**1.46**	**1.4**	**0.98**	**1.06**	**1.13**	**1.04**	**0.64**
3) INPUT: Big SS to slicer **kg**	2.94	3.78	2.12	3.70	4.22	3.00	4.06	3.38	4.42	4.98	3.10	2.70	4.02	2.82	1.92
Time of slicer **min:sec**	00:00:12	00:00:11	00:00:10	00:00:15	00:00:13	00:00:08	00:00:11	00:00:09	00:00:13	00:00:17	00:00:15	00:00:12	00:00:10	00:00:09	00:00:09
Time of slicer **sec**	12	11	10	15	13	8	11	9	13	17	15	12	10	9	9
Even slices of Topside SS	2.88	3.66	1.80	3.44	4.20	2.62	3.78	3.20	4.10	4.78	2.86	2.56	4.06	2.82	1.64
Trim	0.06		0.30	0.26		0.36	0.26	0.18	0.30	0.22	0.20	0.14		0.06	0.28
total	**2.94**	**3.66**	**2.10**	**3.70**	**4.20**	**2.98**	**4.04**	**3.38**	**4.40**	**5.00**	**3.06**	**2.70**	**4.06**	**2.88**	**1.92**
4) INPUT: Even slices SS to cutters **kg**	2.88	3.66	1.80	3.44	4.20	2.62	3.78	3.20	4.10	4.78	2.86	2.56	4.06	2.82	1.64
Time of cutter **min:sec**	00:00:30	00:00:38	00:00:19	00:00:32	00:00:33	00:00:23	00:00:37	00:00:23	00:00:36	00:00:42	00:00:22	00:00:12	00:00:43	00:00:19	00:00:13
Time of cutter **sec**	30	38	19	32	33	23	37	23	36	42	22	12	43	19	13
Topside silverside	2.42	2.88	1.72	2.88	3.66	2.50	3.34	3.10	3.88	4.46	2.70	2.46	2.76	2.54	1.52
Lean SB's	0.36	0.46		0.44	0.30								0.50	0.18	
Trim	0.08	0.34	0.08	0.14	0.26	0.12	0.44	0.10	0.16	0.28	0.16	0.10	0.34	0.08	0.12
total	**2.86**	**3.68**	**1.80**	**3.46**	**4.22**	**2.62**	**3.78**	**3.20**	**4.04**	**4.74**	**2.86**	**2.56**	**3.60**	**2.80**	**1.64**
5) INPUT: 1 Big SS for Topside SS	3.12	2.70	2.84	3.04	2.02	2.24	2.08	3.60	2.46	2.54	2.92	3.44	4.14	3.02	2.02
cut by hand **kg**															
Time of cutter **min:sec**	00:00:22	00:00:19	00:00:17	00:00:17	00:00:11	00:00:18	00:00:15	00:00:18	00:00:19	00:00:20	00:00:22	00:00:20	00:00:26	00:00:23	00:00:16
Time of cutter **sec**	22	19	17	17	11	18	15	18	19	20	22	20	26	23	16
Topside SS	2.88	2.44	2.64	2.74	1.68	1.74	1.68	3.20	2.18	2.32	2.58	3.02	3.92	2.68	1.72
Lean SB's	0.20	0.28	0.18	0.32	0.36	0.48	0.40	0.42	0.20	0.16	0.32	0.42	0.22	0.20	0.30
Trim	0.04		0.02			0.04			0.08	0.06				0.14	
Total	**3.12**	**2.72**	**2.84**	**3.06**	**2.04**	**2.26**	**2.08**	**3.62**	**2.46**	**2.54**	**2.90**	**3.44**	**4.14**	**3.02**	**2.02**

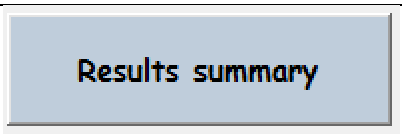
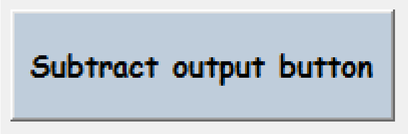
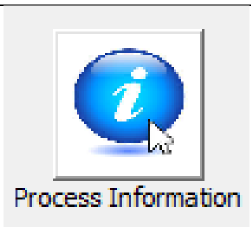
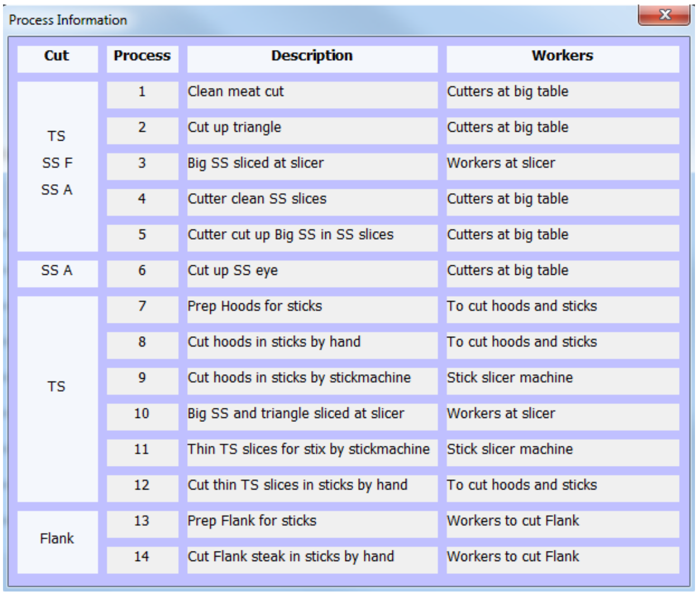
6) Hoods to cut in half **kg**	1.04	0.98	0.92	0.56	0.88	0.76	0.86	0.86	0.78	0.70	0.70	0.66	0.58	0.68	1.12	0.88	0.72	0.80	1.24	0.76	0.76	0.50	0.72	0.94	0.78	0.46	0.64	0.50	0.50	0.64
Time of cutter **min:sec**	00:03:20	00:02:13	00:00:39	00:00:38	00:00:30	00:00:31	00:01:06	00:00:40	00:00:53	00:00:52	00:00:52	00:01:02	00:00:50	00:00:43	00:01:48	00:01:20	00:01:01	00:01:30	00:01:33	00:01:15	00:01:03	00:00:58	00:01:02	00:01:20	00:01:04	00:00:30	00:00:45	00:00:38	00:00:52	00:01:06
Time of cutter **sec**	200	133	39	38	30	31	66	40	53	52	52	62	50	43	108	80	61	90	93	75	63	58	62	80	64	30	45	38	52	66
Hoods cut in half	0.96	0.96	0.90	0.52	0.86	0.76	0.84	0.86	0.76	0.68	0.70	0.54	0.54	0.62	1.02	0.72	0.66	0.72	1.06	0.66	0.72	0.42	0.68	0.86	0.74	0.45	0.60	0.44	0.48	0.64
Fat, Trim, Sinew for sausage	0.06	0.02	0.01	0.02	0.02		0.02		0.02	0.02	0.02	0.14	0.04	0.06	0.10	0.14	0.06	0.10	0.18	0.08	0.04	0.08	0.06	0.08	0.04	0.01	0.04	0.05	0.02	1.06
Total	**1.02**	**0.98**	**0.91**	**0.54**	**0.88**	**0.76**	**0.86**	**0.86**	**0.78**	**0.70**	**0.72**	**0.68**	**0.58**	**0.68**	**1.12**	**0.86**	**0.72**	**0.82**	**1.24**	**0.74**	**0.76**	**0.50**	**0.74**	**0.94**	**0.78**	**0.46**	**0.64**	**0.49**	**0.50**	**1.70**
7) INPUT: hoods cut in half to																														
cut by hand **kg**	0.96	0.96	0.90	0.52	0.86	0.76	0.86	0.86	0.78	0.70	0.70	0.54	0.54	0.62	1.02	0.72	0.66	0.72	1.06	0.66	0.72	0.42	0.68	0.86	0.74	0.45	0.60	0.44	0.48	0.62
Time of cutter **min:sec**	00:07:20	00:10:02	00:08:30	00:08:10	00:09:10	00:05:40	00:06:30	00:07:30	00:07:40	00:05:08	00:00:45	00:00:50	00:00:58	00:00:57	00:01:30	00:01:10	00:00:58	00:00:51	00:01:29	00:00:45	00:01:40	00:01:00	00:01:15	00:01:18	00:01:10	00:00:37	00:01:11	00:00:38	00:00:50	00:00:52
Time of cutter **sec**	440	602	510	490	550	340	390	450	460	308	45	50	58	57	90	70	58	51	89	45	100	60	75	78	70	37	71	38	50	52
Sticks	0.70	0.90	0.80	0.48	0.78	0.72	0.80	0.78	0.68	0.64	0.68	0.54	0.50	0.62	1.02	0.72	0.66	0.70	1.04	0.66	0.70	0.52	0.56	0.86	0.74	0.46	0.60	0.44	0.48	0.60
Trim	0.08	0.04	0.10	0.08	0.04	0.02	0.04	0.08	0.08	0.06			0.02								0.02									
Total	**0.78**	**0.94**	**0.90**	**0.56**	**0.82**	**0.74**	**0.84**	**0.86**	**0.76**	**0.70**	**0.68**	**0.54**	**0.52**	**0.62**	**1.02**	**0.72**	**0.66**	**0.70**	**1.04**	**0.66**	**0.72**	**0.52**	**0.56**	**0.86**	**0.74**	**0.46**	**0.60**	**0.44**	**0.48**	**0.60**
8) INPUT: hoods cut in half to																														
stick cutter machine kg	1.52	0.92	0.98	1.26	1.14	1.04	1.22	1.42	1.30	1.30	1.30	0.54	0.96	1.08	1.30	1.14	1.48	1.48	1.06	1.50	1.16	1.62	1.24	1.22	1.26	1.14	0.84	1.20	0.98	0.98
Time of stick machine **min:sec**	00:00:49	00:00:30	00:00:24	00:00:31	00:00:29	00:00:25	00:00:30	00:00:28	00:00:31	00:00:40	00:00:22	00:00:17	00:00:26	00:00:39	00:00:43	00:00:28	00:00:35	00:01:10	00:00:26	00:00:33	00:00:31	00:00:28	00:00:33	00:00:54	00:00:25	00:00:16	00:00:26	00:00:19	00:00:21	00:00:18
Time of stick machine **sec**	49	30	24	31	29	25	30	28	31	40	22	17	26	39	43	28	35	70	26	33	31	28	33	54	25	16	26	19	21	18
Sticks	1.52	0.88	0.92	1.26	1.14	1.04	1.22	1.42	1.28	1.26	1.32	0.54	0.96	1.04	1.30	1.14	1.48	1.44	1.06	1.50	1.16	1.62	1.24	1.22	1.26	1.14	0.84	1.20	0.98	0.96
Trim			0.10							0.04				0.04				0.02												0.02
Total	**1.52**	**0.88**	**1.02**	**1.26**	**1.14**	**1.04**	**1.22**	**1.42**	**1.28**	**1.30**	**1.32**	**0.54**	**0.96**	**1.08**	**1.30**	**1.14**	**1.48**	**1.46**	**1.06**	**1.50**	**1.16**	**1.62**	**1.24**	**1.22**	**1.26**	**1.14**	**0.84**	**1.20**	**0.98**	**0.98**
9) INPUT: Big SS and triangle to slicer **kg**	1.46	1.46	3.78	4.18	3.52	3.98	1.04	1.38	1.46	3.48	1.04	2.50	2.98	0.76	1.08	0.76	2.68	2.06	3.36	0.96	4.00	0.96	1.40	1.08	3.20	0.96	3.26	0.90	3.52	1.18
Time of slicer **min:sec**	00:00:16	00:00:17	00:00:26	00:00:30	00:00:29	00:00:25	00:00:14	00:00:13	00:00:16	00:00:26	00:00:09	00:00:19	00:00:31	00:00:12	00:00:14	00:00:10	00:00:28	00:00:21	00:00:33	00:00:18	00:00:34	00:00:12	00:00:19	00:00:12	00:00:22	00:00:11	00:00:25	00:00:10	00:00:23	00:00:26
Time of slicer **sec**	16	17	26	30	29	25	14	13	16	26	9	19	31	12	14	10	28	21	33	18	34	12	19	12	22	11	25	10	23	26
Thin slices for sticks	1.46	1.24	3.72	4.16	3.22	3.68	1.00	1.32	1.44	3.36	1.04	2.16	2.80	0.76	0.88	0.76	2.48	2.06	3.14	0.76	3.98	0.94	1.26	1.08	2.80	0.96	3.00	0.90	3.32	0.84
Trim		0.22	0.06		0.32	0.30	0.04	0.08		0.12		0.34	0.16		0.16		0.16		0.22	0.20			0.14		0.42		0.26		0.18	0.34
Total	**1.46**	**1.46**	**3.78**	**4.16**	**3.54**	**3.98**	**1.04**	**1.40**	**1.44**	**3.48**	**1.04**	**2.50**	**2.96**	**0.76**	**1.04**	**0.76**	**2.64**	**2.06**	**3.36**	**0.96**	**3.98**	**0.94**	**1.40**	**1.08**	**3.22**	**0.96**	**3.26**	**0.90**	**3.50**	**1.18**
10) INPUT: thin slices to																														
stick cutter machine **kg**	1.46	1.24	3.72	4.16	3.22	3.68	1.00	1.32	1.44	3.36	0.96	1.34	1.90	1.90	2.08	2.54	2.24	2.24	3.02	2.60	2.00	1.54	1.90	2.74	1.80	1.36	2.50	2.26	2.64	3.16
Time of stick machine **min:sec**	00:00:22	00:00:16	00:00:45	00:01:00	00:00:40	00:00:51	00:00:15	00:00:22	00:00:35	00:00:40	00:00:15	00:00:21	00:00:42	00:00:31	00:00:30	00:00:29	00:00:22	00:00:28	00:00:33	00:00:35	00:00:25	00:00:17	00:00:24	00:00:25	00:00:48	00:00:30	00:00:29	00:00:26	00:00:50	00:01:02
Time of stick machine **sec**	22	16	45	60	40	51	15	22	35	40	15	21	42	31	30	29	22	28	33	35	25	17	24	25	48	30	29	26	50	62
finish sticks	1.48	1.24	3.72	4.16	3.22	3.68	1.00	1.32	1.44	3.36	0.96	1.34	1.90	1.90	2.08	2.54	2.24	2.24	3.02	2.60	2.00	1.54	1.90	2.74	1.72	1.32	2.50	2.26	2.60	3.12
Trim													0.02						0.02	0.02					0.06	0.04	0.02		0.02	0.02
Total	**1.48**	**1.24**	**3.72**	**4.16**	**3.22**	**3.68**	**1.00**	**1.32**	**1.44**	**3.36**	**0.96**	**1.34**	**1.92**	**1.90**	**2.08**	**2.54**	**2.24**	**2.24**	**3.04**	**2.62**	**2.00**	**1.54**	**1.90**	**2.74**	**1.78**	**1.36**	**2.52**	**2.26**	**2.62**	**3.14**
11) INPUT: thin slices to cut by hand **kg**	3.26	0.88	4.12	0.90	4.12	0.88	2.86	1.12	2.16	1.00	1.04	2.16	2.80	0.76	0.85	0.76	2.48	2.06	3.14	0.76	3.98	0.94	1.26	1.08	2.80	0.96	3.00	0.90	3.32	0.84
Time of cutter **min:sec**	00:07:00	00:01:18	00:04:38	00:02:01	00:06:27	00:02:13	00:04:23	00:01:58	00:04:02	00:01:27	00:01:48	00:03:14	00:02:50	00:00:58	00:00:54	00:00:51	00:02:25	00:02:13	00:02:39	00:01:04	00:05:50	00:02:15	00:02:44	00:02:29	00:05:54	00:03:01	00:06:52	00:01:56	00:08:20	00:02:20
Time of cutter **sec**	420	78	278	121	387	133	263	118	242	87	108	194	170	58	54	51	145	133	159	64	350	135	164	149	354	181	412	116	500	140
finish sticks	3.24	0.88	4.12	0.86	4.12	0.88	2.84	1.10	2.16	0.98	1.02	2.12	2.80	0.76	0.90	0.74	2.46	2.06	3.12	0.72	3.92	0.80	1.08	0.86	2.78	0.80	2.94	0.80	3.28	0.82
Trim	0.02			0.04				0.02		0.02	0.02	0.02	0.02			0.02	0.02		0.02	0.06	0.04	0.14	0.16	0.18	0.02	0.14	0.02	0.08	0.02	0.01
Total	**3.26**	**0.88**	**4.12**	**0.90**	**4.12**	**0.88**	**2.84**	**1.12**	**2.16**	**1.00**	**1.04**	**2.14**	**2.82**	**0.76**	**0.90**	**0.76**	**2.48**	**2.06**	**3.14**	**0.78**	**3.96**	**0.94**	**1.24**	**1.04**	**2.80**	**0.94**	**2.96**	**0.88**	**3.30**	**0.83**

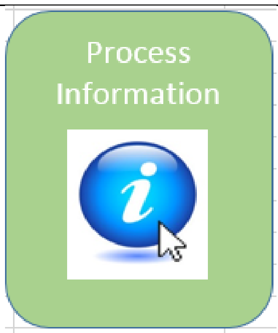
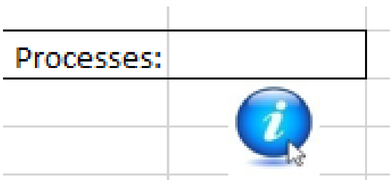
Flank Steak

A Grade Flank steak	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
1) INPUT: 1 Flank steak **kg**	0.7	0.52	0.64	0.88	0.58	0.56	0.56	0.64	0.62	0.54	0.5	0.6	0.64	0.68	0.62	0.74	0.64	0.52	0.5	0.64	0.8	0.54	0.52	0.58	0.56	0.6	0.6	0.62	0.64	0.64
Time of 1 cutter **min:sec**	00:00:48	00:00:58	00:00:57	00:01:10	00:00:52	00:01:00	00:01:00	00:00:50	00:00:42	00:00:57	00:00:50	00:00:59	00:01:00	00:01:00	00:00:42	00:00:58	00:00:57	00:01:34	00:00:55	00:00:51	00:00:58	00:00:52	00:00:38	00:01:01	00:00:48	00:01:20	00:00:54	00:00:58	00:00:47	00:00:35
Time of 1 cutter **sec**	48	58	57	70	52	60	60	50	42	57	50	59	1	1	42	58	57	94	55	51	58	52	38	31	48	80	54	58	47	35
Trim and Fat	0.04	0.02	0.08	0.22	0.06	0.08	0.12	0.1	0.06	0.06	0.06	0.12	0.12	0.08	0.04	0.12	0.1	0.08	0.04	0.06	0.2	0.08	0.06	0.1	0.04	0.18	0.08	0.06	0.1	0.14
Fleece (waste)	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.04	0.02	0.02	0.04	0.02	0.02	0.04	0.04	0.08	0.04	0.02	0.06	0.04
Flat pieces for sticks	0.64	0.48	0.56	0.66	0.5	0.48	0.44	0.52	0.54	0.46	0.42	0.46	0.48	0.56	0.54	0.6	0.52	0.38	0.44	0.54	0.56	0.42	0.44	0.44	0.48	0.44	0.48	0.5	0.5	0.44
total	**0.69**	**0.51**	**0.65**	**0.9**	**0.58**	**0.58**	**0.57**	**0.63**	**0.62**	**0.53**	**0.5**	**0.6**	**0.62**	**0.66**	**0.6**	**0.73**	**0.64**	**0.5**	**0.5**	**0.62**	**0.8**	**0.52**	**0.52**	**0.58**	**0.56**	**0.7**	**0.6**	**0.58**	**0.66**	**0.62**
2) INPUT: Flat pieces for sticks to	0.64	0.48	0.56	0.66	0.5	0.48	0.44	0.52	0.54	0.46	0.42	0.46	0.48	0.56	0.54	0.6	0.52	0.38	0.44	0.54	0.56	0.42	0.44	0.44	0.48	0.44	0.48	0.5	0.5	0.44
cut by hand **kg**																														
Time of cutter **min:sec**	00:00:50	00:00:33	00:00:30	00:00:42	00:00:33	00:00:22	00:00:26	00:00:27	00:00:26	00:00:21	00:00:20	00:00:21	00:00:22	00:00:25	00:00:24	00:00:22	00:00:25	00:00:16	00:00:18	00:00:22	00:00:25	00:00:15	00:00:15	00:00:17	00:00:17	00:00:16	00:00:15	00:00:18	00:00:16	00:00:17
Time of cutter **sec**	50	33	30	42	33	22	26	27	26	21	20	21	22	25	24	22	25	16	18	22	25	15	15	17	17	16	15	18	16	17
Sticks	0.64	0.48	0.56	0.66	0.5	0.48	0.44	0.52	0.54	0.46	0.42	0.46	0.48	0.56	0.54	0.6	0.52	0.38	0.44	0.54	0.56	0.42	0.44	0.44	0.48	0.44	0.48	0.5	0.5	0.44
total	**0.64**	**0.48**	**0.56**	**0.66**	**0.5**	**0.48**	**0.44**	**0.52**	**0.54**	**0.46**	**0.42**	**0.46**	**0.48**	**0.56**	**0.54**	**0.6**	**0.52**	**0.38**	**0.44**	**0.54**	**0.56**	**0.42**	**0.44**	**0.44**	**0.48**	**0.44**	**0.48**	**0.5**	**0.5**	**0.44**

Appendix F: Button Functions

Table F.1: Production management model button function description

<table>
<tr><th>User Form Buttons</th><th>Button Function Description</th></tr>
<tr><td>
</td><td>User form shows previous values that where inserted in the user form.</td></tr>
<tr><td>
</td><td>Opens the result summary sheet where the average plus and minus standard deviation values are given of the input, time, and cost of each of the 4 scenarios or option.</td></tr>
<tr><td>
</td><td>Subtracts the orders outputs already covered by the user from the remaining order amounts.</td></tr>
<tr><td>
</td><td>Opens the following window below. This window provides a description of each process, the processes associated with each meat cut and the workers that work on the specific process, as shown below.

Process Information
<table>
<tr><th>Cut</th><th>Process</th><th>Description</th><th>Workers</th></tr>
<tr><td rowspan="5">TS
SS F
SS A</td><td>1</td><td>Clean meat cut</td><td>Cutters at big table</td></tr>
<tr><td>2</td><td>Cut up triangle</td><td>Cutters at big table</td></tr>
<tr><td>3</td><td>Big SS sliced at slicer</td><td>Workers at slicer</td></tr>
<tr><td>4</td><td>Cutter clean SS slices</td><td>Cutters at big table</td></tr>
<tr><td>5</td><td>Cutter cut up Big SS in SS slices</td><td>Cutters at big table</td></tr>
<tr><td>SS A</td><td>6</td><td>Cut up SS eye</td><td>Cutters at big table</td></tr>
<tr><td rowspan="6">TS</td><td>7</td><td>Prep Hoods for sticks</td><td>To cut hoods and sticks</td></tr>
<tr><td>8</td><td>Cut hoods in sticks by hand</td><td>To cut hoods and sticks</td></tr>
<tr><td>9</td><td>Cut hoods in sticks by stickmachine</td><td>Stick slicer machine</td></tr>
<tr><td>10</td><td>Big SS and triangle sliced at slicer</td><td>Workers at slicer</td></tr>
<tr><td>11</td><td>Thin TS slices for stix by stickmachine</td><td>Stick slicer machine</td></tr>
<tr><td>12</td><td>Cut thin TS slices in sticks by hand</td><td>To cut hoods and sticks</td></tr>
<tr><td rowspan="2">Flank</td><td>13</td><td>Prep Flank for sticks</td><td>Workers to cut Flank</td></tr>
<tr><td>14</td><td>Cut Flank steak in sticks by hand</td><td>Workers to cut Flank</td></tr>
</table></td></tr>
<tr><td>
</td><td>This button cleans all the Excel sheets and the user form.</td></tr>
</table>

Excel Sheet Buttons	Button Function Description
	Opens user form with previous user form inserted values.
	Open new user form and cleans Excel sheets.
	Opens the result summary sheet automatically where the average plus and minus standard deviation values are given of the input, time, and cost of each of the 4 scenarios or option.
 	Both of these buttons open the process information window. This window provides a description of each process, the processes associated with each meat cut and the workers that work on the specific process.

Appendix G: SAJIE Article

A CONCEPTUAL FRAMEWORK TO INCREASE COMPETITIVENESS IN A BILTONG FACTORY

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ARTICLE INFO

Article details
Presented at the 29th annual conference of the South African Institute for Industrial Engineering (SAIIE), held form 24-26 October 2018 in Stellenbosch, South Africa

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DOI
http://dx.doi.org/10.7166/29-3-2053

ABSTRACT

The global annual biltong market value was estimated at roughly R640 million to R1.1 billion in 2003. By 2015, biltong sales were reported to be more than R2.5 billion. To stay competitive as a biltong manufacturing company in an ever-changing landscape, the company's success is determined by efficient operations. To achieve efficient operations, the accurate determination of performance measurements is of utmost importance. In world-class manufacturing facilities, one of the primary features of performance measurement is the measurement of cycle time. Although there is an emphasis, especially in Industry 4.0, on real-time data, the biltong factory where this study was conducted is still very much a manual operation. The focus of this study is, therefore, rather on performance measurements in order to achieve efficient operations and competitiveness. The aim of this study is to present different competitive advantage concepts in order to build a production management model. The biltong factory has not yet established cycle times for their production activities. A production management model has the potential to be used by the factory to manage their production processes more efficiently, and ultimately to increase their competitiveness.

OPSOMMING

Die globale jaarlikse biltongmarkwaarde is in 2003 beraam as R640 miljoen tot R1.1 miljard. Dit is gerapporteer dat biltongverkope teen 2015 sal vermeerder tot meer as R2,5 miljard. Om hierdie verkope verder te vermeerder en om mededingendheid te verseker as 'n individuele maatskappy in 'n veranderende besigheidslandskap, word die sukses van die produk bepaal deur doeltreffende bedrywighede. Om doeltreffende bedrywighede te bereik, is die akkurate bepaling van prestasiemetings uiters belangrik. In wêreldklas-vervaardigingsaanlegte, is een van die primêre kenmerke van prestasiemetings die meting van siklustyd. Alhoewel daar klem gelê word op 'Industry 4.0' as verwysing en veral op werklike tyd data, gebruik die biltong-fabriek waar hierdie studie uitgevoer is nog steeds mens-gedrewe fasiliteite. Om hierdie rede is die fokus van hierdie studie om (met betrekking tot prestasiemetings) doeltreffende bedrywighede en mededingendheid te behaal en te volhou. Dus, is die doel van hierdie studie om verskillende mededingende voordeel konsepte te ondersoek om ten einde 'n produksiebestuursmodel te bou. Die biltong-fabriek het tans nie gevestigde data vir siklustye met betrekking tot hul produksie-aktiwiteite nie. Daarom is 'n vereiste vir hierdie model om die siklusstye vir hul produksie-aktiwiteite te bepaal. Hierdie model kan deur die fabriek gebruik word om hul produksie doeltreffend te bestuur en uiteindelik hul mededingendheid te verbeter.

1 INTRODUCTION

Biltong and droëwors are popular traditional, high-value snacks in Southern Africa. Often comparisons are made with other international dried meat products such as charqui, carne seca, carne do sol (South America), and beef jerky (North America). However, biltong differs in its taste, production process, and end-product characteristics [1]. Biltong is made of meat that is cut into strips, seasoned with spices and vinegar, and then dried with hot air, while droëwors is a hot-air dried sausage [2],[3]. The process of making biltong is standard, and it is manufactured at a variety of levels, from large-scale factories for industry markets to small-scale butcheries, family businesses, or manufacturing at home for smaller markets [1], [4]. Although the manufacturing steps stay the same, the manufacturing processes for large-scale production and small-scale family businesses differ in the type of technology used and the quantity produced, which results in a mixed market of unbranded and branded products [2].

Biltong has become a staple regular part of the South African diet over the years. The annual biltong market value, in 2003, was estimated at roughly R640 million to R1.1 billion [5]. According to Saayman [6], a North-West University study reported biltong sales to be in excess of R2.5 billion in 2015: sales of beef biltong constituted R2.4 billion, while game biltong constituted R237 million [6]. The price drivers in the biltong industry include the popularity of the meat used, the cost of the animal, and the cost of processing [6]. The biltong market is extremely diverse and competitive, and the company with the best price and quality often prevails as the customer's preferred choice.

To stay competitive in an ever-changing landscape, a company's success is determined by efficient operations. For a company to achieve a competitive position, performance monitoring is essential [7]. Therefore, an essential aspect of effective manufacturing strategies or competitiveness is regularly tracking and monitoring performance [8]. Establishing performance measures enables a company to identify efficient ways to do things and to implement them. Although there is an emphasis, especially with regard to Industry 4.0, on real-time data, the biltong factory where this study was conducted (name not disclosed) is still very much a manual operation with no real-time data. The focus of this study, therefore, is to develop a production management model that uses performance measurement data to determine the scheduling and process routings, and that adapts to the orders received to achieve flexible efficient operations and competitiveness. A production management model has the potential to be used by the factory to manage its production processes more efficiently, bringing down the cost of production and ultimately increasing its competitiveness.

2 METHODOLOGY FRAMEWORK FOR DEVELOPING MODEL

In order to improve the competitiveness of a manufacturing company and to be competitive in the Industry 4.0 environment, companies need to adopt new methods and technologies. However, this is often a costly venture, and it may not result in a significant return on investment (ROI) for the company. A production management model is proposed to assist companies in becoming more competitive without substantial change to their structure and day-to-day business. Figure 1 illustrates the methodology that was followed in order to determine the model function and the area that needed to be focused on in the use case to implement improvement.

The first step of the methodology framework was to conduct research on competitive advantage concepts and tools. This information was then used to develop the model specifically for the biltong factory, in order to analyse the factory and to determine an area needing improvement. After an area for improvement was established, the data required to develop the production management model was determined. The model function was then established. Each section of the methodology framework will be discussed in greater detail in the sections that follow.

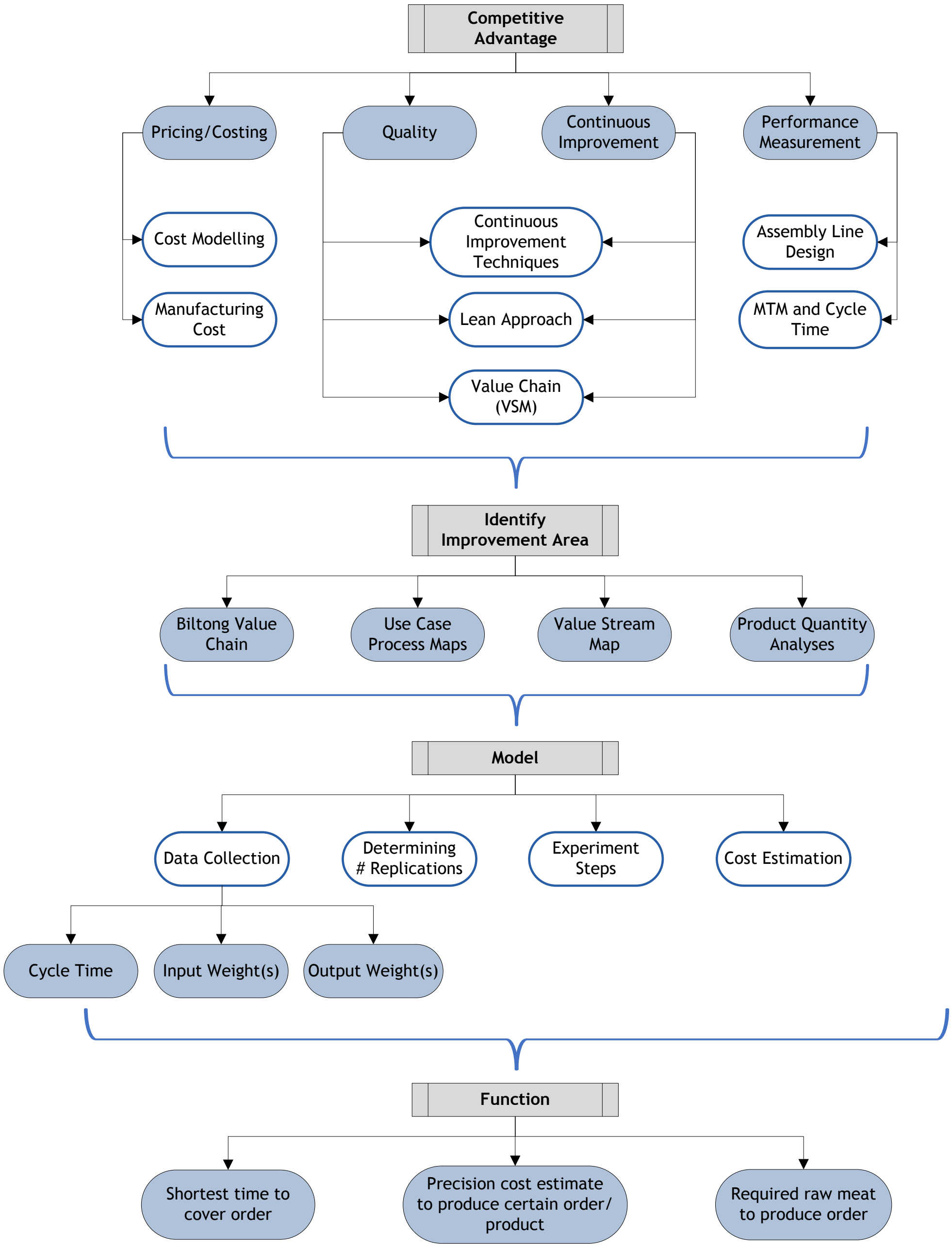


Figure 1: Methodology framework for developing biltong production management model

3 COMPETITIVE ADVANTAGE CONCEPTS

The research focused on different competitive advantage concepts. According to Mayer and Nusswald [12], an enterprise's success is measured in terms of three global economic goals: high quality, low lead times, and low costs. These three main goals were the cornerstones for the conducted research; and, based on them, the main focus areas for achieving competitive advantage [13]-[21] were identified as: cost and pricing ([13], [16], [21]), quality ([22], [23]), continuous improvement ([24]-[26]), and performance measurement ([7]-[12], [27]).

The first parameter for competitive advantage, cost and price, was investigated further by conducting a literature study on cost modelling techniques ([19], [22], [27]-[30]) and types of manufacturing costs ([13], [22], [27]-[29], [31]-[33]). For continuous improvement, and the quality cornerstones, different continuous improvement techniques ([26], [34]-[40]) were analysed. It was decided, from all the different continuous improvement techniques studied, that the Lean approach was best suited for this study, and thus further research was conducted on Lean ([16], [36], [41]-[45]). The Lean concepts — cost reduction and flow (Tapping, Luyster and Shuker, 2002) — also refer to the costing or pricing and the performance measurement cornerstones of competitive advantage. Tools to implement Lean were also considered. These tools included value stream mapping (VSM) ([4], [11], [16], [21], [41]-[42], [44], [46]-[47]) and assembly line design (Groover, 2015). Under VSM, the food supply chain and biltong value chain ([4], [48]-[49]) were investigated. Aspects of assembly line design, including the importance of performance measurements ([43], [50]-[53]), and more specifically cycle time ([9], [25], [27], [43], [50], [53]-[55]), were also studied.

Some important literature concepts that were used to determine the focus area and function of the production management model are discussed in greater detail in the next sections.

3.1 Value stream mapping

According to Rother and Shook [11], a value stream perspective means taking a 'big-picture' perspective to improve the whole stream. The value stream is described in the literature as the set of actions or activities that bring the product from raw material to finished goods, from order to delivery, or from concept to realisation [44]. The value stream also focuses downstream on creating what the customer views as value. By referring to the specific parts in the firm that adds value to the product [16], a contingent view of the value-adding processes is provided. Therefore, the value stream differs from a supply chain or value chain, which includes the activities of all the companies involved [42].

The biltong value chain was mapped, and the segment where the biltong factory is located was identified first. The factory's process maps were also established in order to get a big-picture perspective; then the VSM of the use case was developed to analyse the company's operations and value structure.

3.2 Quality vs price

According to Buxton *et al*. [23], in some industries quality or non-price factors can be as important as, or more important than, price. In most markets there are essentially many more dimensions to quality than price on which competitors can differentiate a product and/or service. Thus in some industries it is more likely that the quality factor will be decisive in influencing the customer's choice [23]. The 'wow factor' at the customer level of exchange is to provide a product/service that would not only satisfy customers but "make your customers successful" [16]. This is specifically important in the biltong factory use case, where the customer is often not the consumer of the product, but rather a reseller. To identify an improvement area, the biltong factory's value that it provides to its customers needs to be understood.

3.3 Lean

When implementing Lean, one of the important tenets is the seamless movement through value-creating activities [44]. According to Braglia *et al*. [41], one of the design questions for a future state map is: What single point within the production chain can be used to schedule production? Product-quantity analysis is one of the methods that can be employed to determine which value stream(s) to target in order to implement improvements. This analysis is done by determining whether some part numbers have high enough volumes to target as the value stream [45].

To determine what processes the model must focus on as the initial target for implementing improvements, the literature on Lean and product-quantity analysis was used. The first step of the improved VSM procedure is to select a product family. This involves identifying the product families in order to select one in which to implement improvements. A product family is defined as a group of products that pass through similar steps in the process and over common equipment in the downstream processes [41].

3.4 Cycle time

One of the cornerstones of effective manufacturing strategies is to track and monitor performance regularly [8]. Cycle time is a primary feature of performance measurement, and can be used as an indicator to measure the efficiency of a production process [11]. This finding is supported by Maskell [10], who states that, for world class manufacturing, a primary feature of performance measurement is the measurement of cycle time [10]. For this reason it was decided to determine the cycle time by measuring the time for each process that forms part of the product families that were previously established. Statistical considerations should also be taken into account when calculating the cycle time.

3.5 Cost modelling/estimation

The cost estimation method used in this study is activity-based costing (ABC) ([13], [22], [27], [31], [32]), as this method assumes that activities drive costs (Steward, Wyskida and Johannes, 1995). ABC is the collection of operational performance and financial information that is related to the significant activities of the business [32]. ABC systems focus on the activities as the fundamental cost objects; the costs for each activity are accumulated as a separate cost object, and then this information is applied to products undergoing the different activities [31]. The basic principle of ABC is that units should bear the cost associated with the activity they cause [13].

4 USE CASE ANALYSES

In this section, the biltong factory is analysed in order to identify the improvement area to focus on. Firstly, the biltong value chain is mapped, from primary producers to end customer. Then the factory processes are mapped in order to develop the VSM of the use case.

4.1 Process mapping

To obtain a big-picture perspective of the biltong factory, an understanding of the biltong value chain and production process is essential. The phase in the biltong value chain on which this study focuses is the *secondary processors and wholesalers* phase, as highlighted in Figure 2.

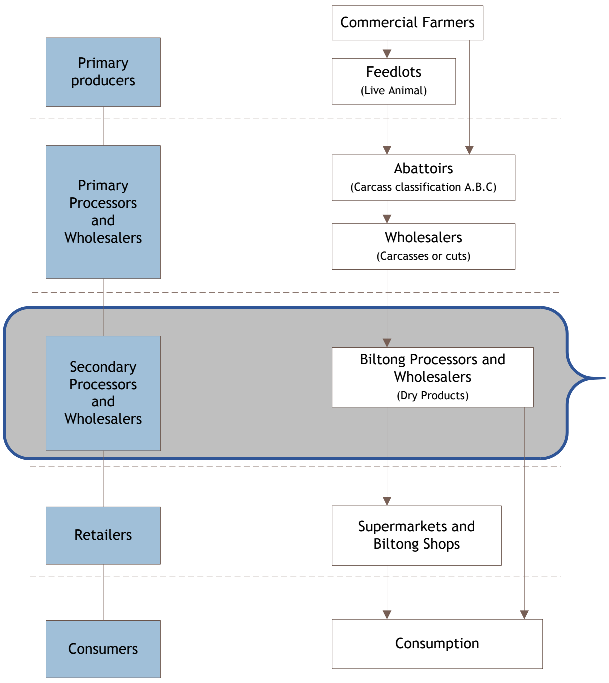


Figure 2: The use case phase within the beef/biltong value chain (adapted from [4])

The specific biltong factory used in this study has two separate factories: the 'wet factory' and the 'dry factory'. The different processes in the two factories were analysed first in order to develop a VSM of the biltong factory.

The 'wet factory' processes the cuts of meat before they are dried. The 'dry factory' operates the managing, drying, and packaging processes to prepare the products before sending them to the various customers. Figures 3 and 4 depict the process maps of the wet and dry factories respectively.

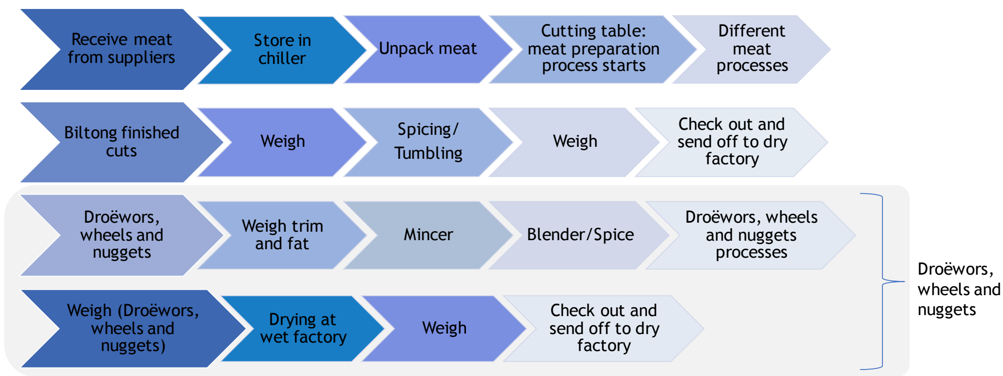


Figure 3: Process map of 'wet factory'

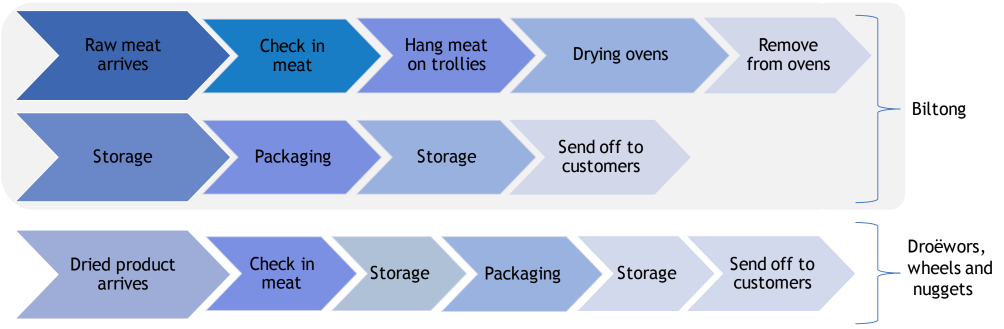


Figure 4: Process map of 'dry factory'

In Figure 4, the meat is received from the primary processors (see Figure 2). These suppliers are also the primary producers of the meat, as they have their own feedlots to ensure consistent quality. The meat cuts are prepared/cleaned at the cutting table before they are moved to the different processes to produce the final products. Two of the outputs at the cutting table are trim and fat, which are used in the products that are made from minced meat. The processing of the biltong varies, depending on the type of product and customer requirements. The droëwors, wheels, and nuggets are dried at the 'wet factory'. The finished products are then sent to the 'dry factory' for packaging and distribution. On the other hand, the spiced wet biltong cuts are sent to the 'dry factory' for drying, packaging, and distribution.

4.2 Value stream map

The VSM was developed, based on the research conducted and on information collected directly from the biltong factory after an indepth analysis of the processes had been completed. The VSM depicted in Figure 5 uses the actual state or current state icons [41] to map the value stream of the whole biltong factory. Thus the VSM includes both the 'wet factory' and 'dry factory' activities.

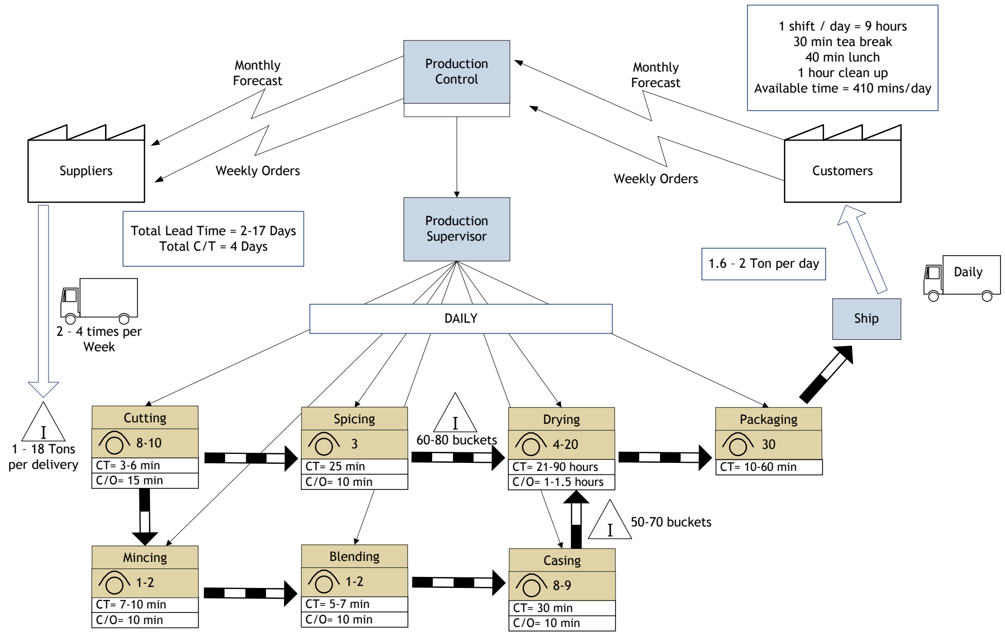


Figure 5: Value stream map of the biltong factory use case

The biltong factory has ±50 different suppliers who supply raw meat cuts, spice, and packaging material to the biltong factory. The suppliers' lead times differ, depending on the product and quantity ordered. The cycle time is based on the process time per bucket — i.e., the time taken to complete ±60 kilograms of meat product. The changeover time for each process includes the time to clean the stations, machines, and/or drying units between different batches of products.

All of the processes shown in Figure 5 add value to the products and, in effect, create value for customers, as they are influenced by the customers' requirements. They can request a certain thickness of product, a certain dryness, a specific spice mix from the biltong factory's recipes, and even specific packaging and labels for their products. This requires the factory setup to be flexible and to allow for mass customisation.

Two value-adding processes that need to be highlighted are drying and cutting. The cutting process is very important in creating value for the company, because, if it is performed with poor precision, the company's profit margin will be reduced. When excess meat is cut off as trim or fat while preparing the biltong products, the factory loses money on the end products, as trim and fat are part of the minced products. Minced products generally have a lower market value than the biltong products, even though both products originate from the same cut of meat.

During the drying process, the meat loses a minimum of 55% of its original weight. The time required to dry the biltong products is dependent on the type of product being dried, the weather conditions, and the customer's requirements. The drying process is carefully monitored, as it has the greatest impact on the company's profit margin. If the products are dried excessively, the end-products weigh less, resulting in less yield of this product to sell to customers. This is especially prevalent when large batches are dried at the same time in the same drying unit.

When the final process, packaging, is complete, the end product is pushed for shipment to the different customers. The biltong factory supplies products to roughly 1000 customers, who vary from small biltong shops to big retail stores; and the lead time for delivery depends on the customer's geographic location.

The total lead time to complete an order from when it is received ranges between 2 and 17 days, as depicted in Figure 5. The lead time of 17 days arises in extreme cases, such as when full customisation is required from a customer, all of the required material is not available to complete an order, and/or the supplier is out of stock.

4.3 Identify improvement area

To identify an improvement area, the value that the biltong factory provides to customers must be clearly understood. A primary factor behind the biltong factory's brand loyalty is the high quality of its products. Hence, in this specific case, the aspect of quality is of greater significance than the aspect of price. The 'wow factor' of value is provided to the biltong resellers by supplying them with superior quality products, as this creates high end-customer satisfaction, which in turn ensures repeat business for the resellers.

Another point to consider in determining a focus area is that the 'wet factory' must produce more than double the weight of the end products being sold. Therefore, to cover the 1.6 to 2 tons of products being shipped per day, as depicted in the VSM, the 'wet factory' must produce between 3.5 and 4.5 tons of wet products per day. Thus there is great pressure on the 'wet factory' to produce enough wet products to satisfy customers' orders. For this reason, it can be stated that the 'dry factory' is dependent on the 'wet factory'.

The single-point process (as described by Braglia *et al.* [41]) to be used to schedule production and improve the production flow for this use case is the cutting process. This is the starting point for all the various products, as seen in the VSM, with all the other value-added processes following the cutting process. It can therefore be stated that, all the value-added processes are dependent on the cutting process. Based on this reasoning, it was decided to emphasise the cutting process in the 'wet factory' as the main focus area in which to implement initial improvements.

A product-quantity analysis showing the percentage sales volumes of the biltong factory's products over a three-month period is shown in Table 1. It clearly illustrates that the four highlighted products are responsible for almost 80% of sales.

Table 1: Percentage sale volumes for biltong product groups

Product group name	Sales %	Beef input required
Silversides	12.48%	Silverside flats/ Silverside A grade
Silverside eyes	0.01%	Silverside A grade
Silverside triangle	0.31%	Silverside flats/ Silverside A grade
Sliced biltong (SB)	25.44%	Silverside flats/ Silverside A grade/ Topside
Baby biltong	0.90%	Topside
Chips	0.49%	Topside
Shredder/shaved biltong	0.32%	Topside
Salad cuts	0.26%	Topside
Snapsticks	21.27%	Topside/ flank steak
Topside silverside lean	1.84%	Topside
Beef nuggets	6.67%	Trim and fat
Biltong wheels	0.21%	Trim and fat
Beef droëwors	19.16%	Trim and fat
Chicken (droëwors/sticks/nuggets)	0.79%	
Game (biltong/droëwors)	1.45%	
Kudu (biltong/droëwors)	3.35%	
Ostrich (biltong/droëwors)	3.23%	
Springbok (biltong/droëwors)	1.79%	

It was observed that the higher-selling products (more than 10%) all require silverside flats, silverside A grade, and topside or flank steak cuts. The beef droëwors consists of trim and fat from these steak cuts as they go through the different cutting processes.

In order to determine whether these input steak cuts are part of a product family, an understanding of the production routes was sought. The production routing maps of the different meat cuts were developed in Microsoft Visio®. Figure 6 illustrates an example of one of the topside process routing maps. A comparison of the process routing maps of all the products clearly showed that the products pass through similar steps and use similar equipment. Therefore, this group of products is classified as the 'product family' to target in order to implement improvement.

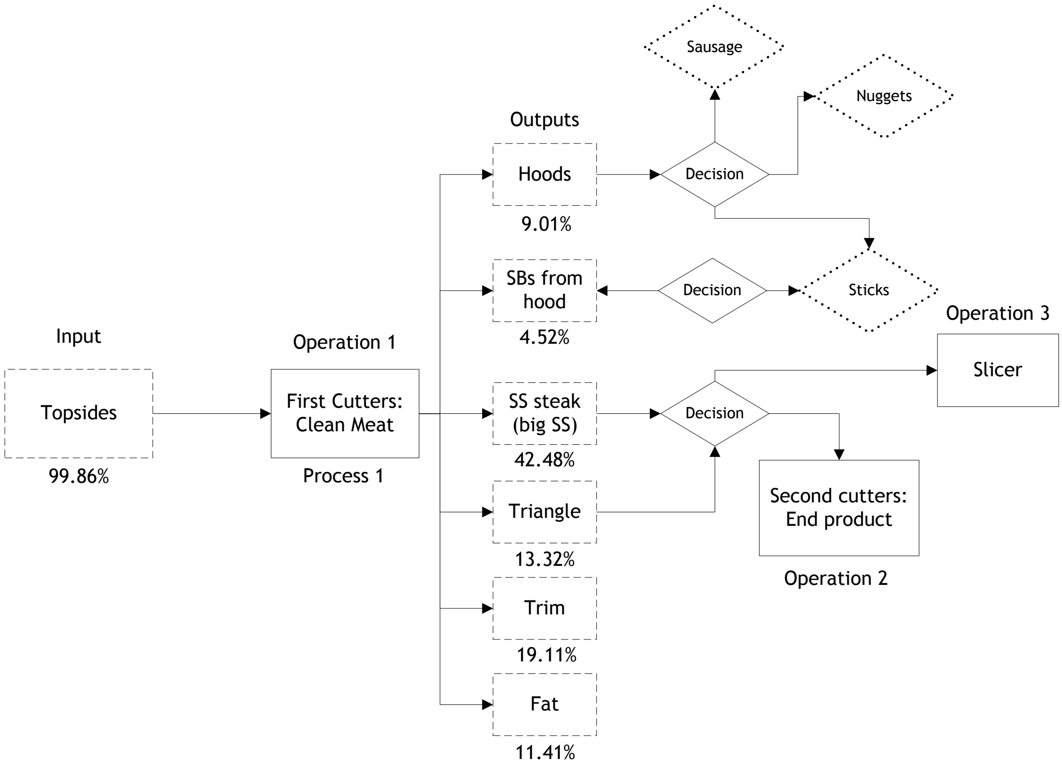


Figure 6: Topside process routing map

5 REQUIRED INFORMATION FOR BILTONG PRODUCTION MANAGEMENT MODEL

The information, experimental steps, and formulas that are required to build a production management model were based on the research conducted and on an understanding of the use case's production. The required information is discussed in the sub-sections below.

5.1 Data collection

The cycle time was only measured for the operation run time of each value-added activity process, as highlighted in circled red in Figure 4.1

To calculate the required number of time study replications to estimate a single mean, the following calculations were carried out in Statistica. The figure below illustrates the t-Test sample size calculation results.

It can be observed in Figure 8 that, in order to detect a standardised effect of δ = 0.62 with 90% power and a significance level of 5%, a sample size of η = 30 replications of each meat process is required. The effect size of δ = 0.62 is sufficient, as it is within the small (0.25) and medium (0.75) effect size range. Therefore, 30 time studies per process were conducted to determine an average output rate per process with a certain statistical power of 90%.

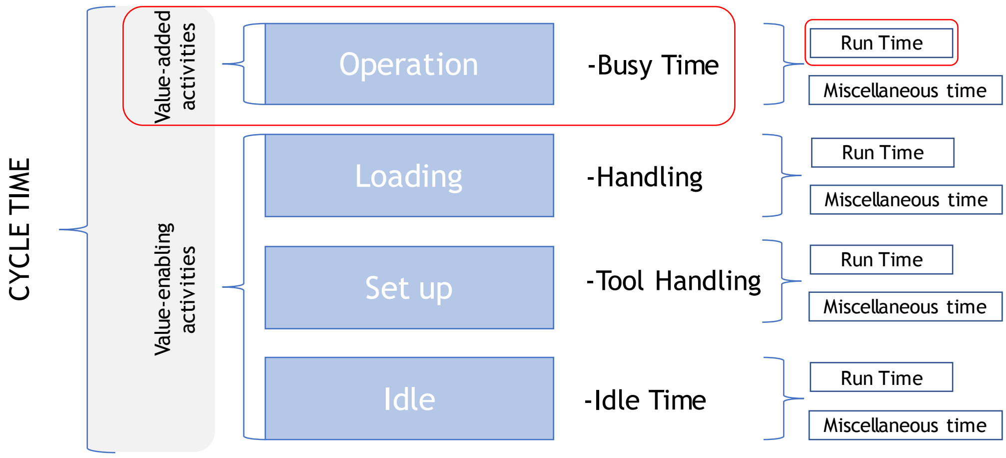
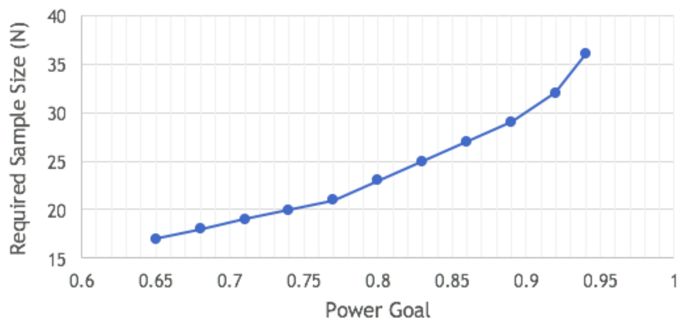


Figure 7: The cycle time components measured for use case



Description	Value
Null hypothesised mean (Mu0)	0.00
True population mean (Mu)	6.20
Population S.D. (Sigma)	10.00
Standardised effect (ES)	0.62
Type I error rate (Alpha)	0.05
Power goal	0.90
Actual power for required N	0.9068
Required sample size	30.00

Figure 8: 1 Sample t-Test sample size calculation (left) and results summarised for the sample size calculation (right)

5.2 Experimental steps

Figure 9 illustrates the experimental steps that were followed when time studies for each process were conducted at the factory. The experiments were done in batches of five and repeated until 30 experiments had been completed.

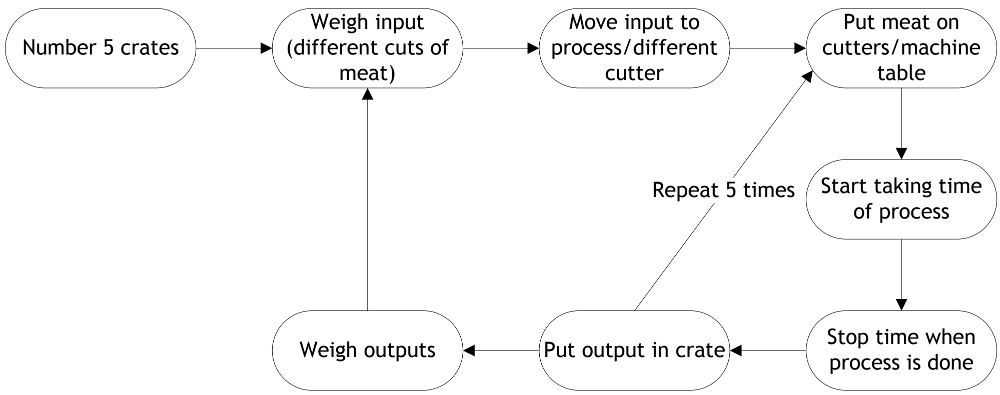


Figure 9: Process followed for time study experiment in biltong factory

5.3 Cost estimation

The cost estimation of manufacturing a product can be used by the factory to determine whether the cost unit bears the cost associated with the activity, as the cost to produce a certain raw product is determined. 'Labour cost' was incorporated to estimate the cost per kg to manufacture a certain amount of biltong. Equations 1 to 3 were developed for the use case, based on research on manufacturing cost calculations [27].

$$\frac{kg}{h}\,[\boldsymbol{output\ rate\ per\ cutter}] \div \frac{Cost}{h}\,[\boldsymbol{Labour\ cost\ per\ cutter}] = \frac{Cost}{kg}\,[\boldsymbol{Labour}] \qquad (1)$$

$$\frac{Cost}{kg}\,[\boldsymbol{Labour}] + \frac{Cost}{kg}\,[\boldsymbol{Fixed\ meat\ cost}] = \frac{Cost}{kg}\,[\boldsymbol{actual\ output\ costs}] \qquad (2)$$

$$\frac{Cost}{kg}\,[\boldsymbol{actual\ output\ costs}] \times \boldsymbol{Number\ of\ cutters} \times \frac{hours}{day} = \boldsymbol{Capacity\ output\ /day} \qquad (3)$$

6 BILTONG PRODUCTION MANAGEMENT MODEL

The model uses the cycle time of the different processes to improve line flow. With line balancing, the manufacturing time is also improved. The cycle time information can be used to calculate the process times and the number of workers required for specific operations. This information can be used to determine the most efficient sequence of processes to complete an order in the shortest time. By improving the manufacturing time and allowing for a higher production rate, efficiency and cost effectiveness will improve.

The model also determines the actual cost of manufacturing the raw meat product by taking into account the labour cost of the 'wet factory' workers. This is achieved by measuring the input and output weight when conducting the cycle time experiments. With this information, the model also calculates the raw meat input needed to produce a certain order output, as well as the time needed to transform the cut of meat. The labour cost to transform the input to a specific output can be estimated with this information. As a result, the production management model can determine the exact time required, the manufacturing cost, and the input required to complete an order.

As the model uses cycle times to provide and manage the information discussed above, the model contributes the following potential benefits identified by [54]:

- Increased throughput
- Reduced costs
- Streamlined processes
- Schedule integrity
- Improved on-time delivery
- Reduced process variability
- Improved communication

7 CONCLUSION

The production management model that will be developed from this framework will assist management with the biltong factory's production processes and, in effect, strengthen its competitive advantage. This will be achieved in an ever-changing market by manufacturing more efficiently. In order to determine the function of the model and the area of focus to implement improvements, different competitive advantage concepts were used. As stated previously, the factory where this study was conducted is still using manual operations, and has not yet embraced Industry 4.0. This model is thus a stepping stone to revolutionising the biltong factory's operational model, allowing for flexible manufacturing and mass customisation while improving competitive advantage.

A production management model framework that uses performance measurement data to determine the scheduling and process routings, and that adapts to the orders received to achieve flexible, efficient operations and competitiveness was developed. The model will help to determine the shortest manufacturing time to produce a certain order; to estimate the cost to manufacture an order, considering labour costs; to determine the amount of raw meat product required to produce an order. The production management model has the potential to be used by the factory to manage its production processes more efficiently, bringing down the cost of production and ultimately increasing its competitiveness.

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Appendix H: Questionnaire Feedback

Questionnaire

Study Background

The adoption of industry 4.0 in South Africa is still low due to a variety of challenges. Some challenges within the context of a typical South African company include that the working environment is labour intensive, low skilled, and low technology driven. Therefore, the typical South African manufacturing SME's are not at the point of implementing industry 4.0 yet. For this reason, this research study rather focusses on developing an approach to increase competitiveness which a company, that does not want to take the industry 4.0 route yet, can follow in order to stay competitive in an ever-changing landscape.

This study will use a Biltong Factory as a use case as a sample of a typical South African manufacturing SME. A production management model was developed for the Biltong Factory to increase their efficiency and in effect their competitiveness. Figure 1 illustrates the approach used to develop the production management model for this Biltong Factory.

Based on the approach followed for the use case and the conducted literature on competitive advantage a generic approach was developed in Figure 2. The questions that follow are based on this generic approach. These questions will be used as validation that the developed approach in this study can be used for a South African manufacturing SME in its endeavour to improve its competitiveness.

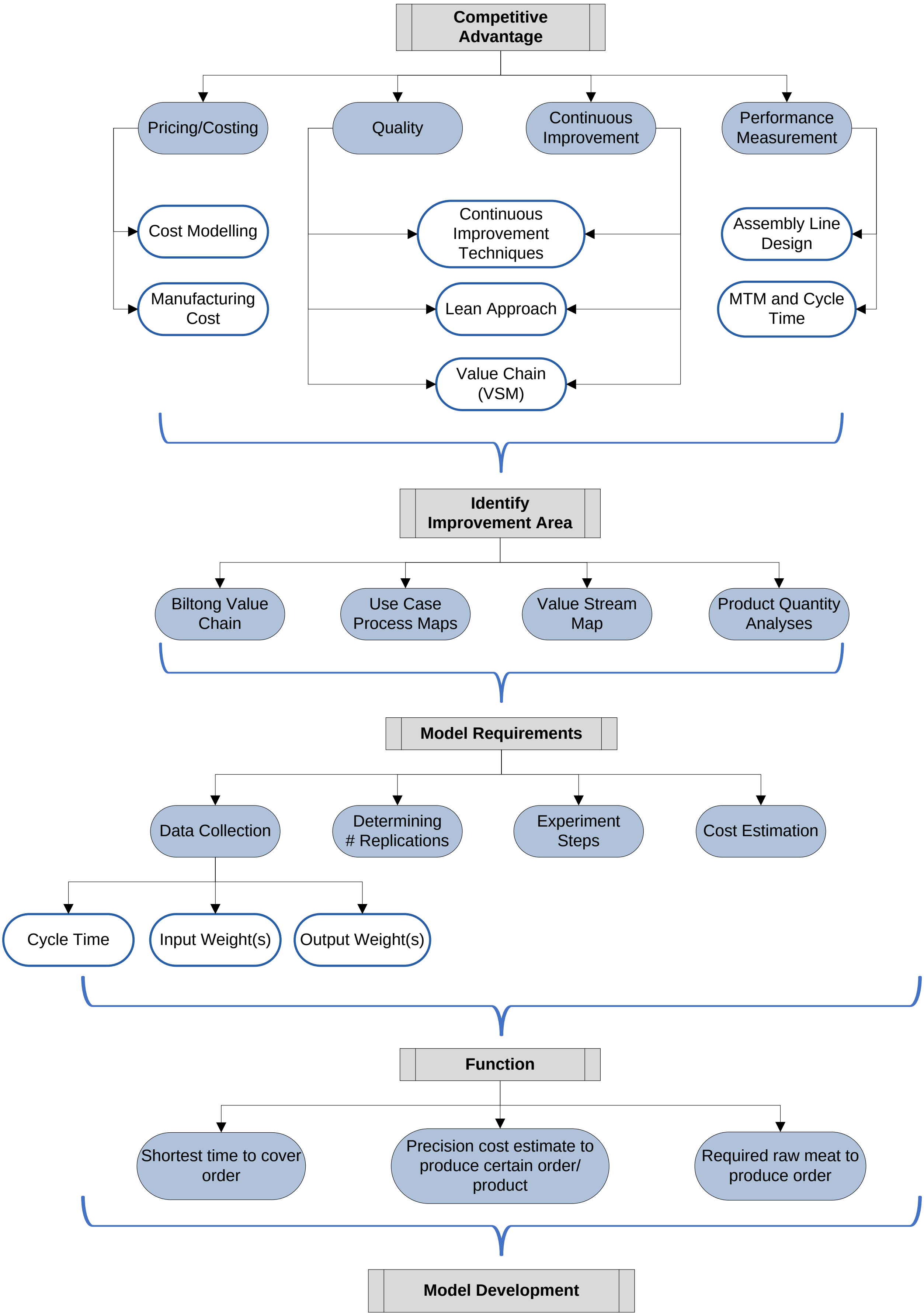


Figure 1: Approach followed to develop a production management model for the Biltong Factory

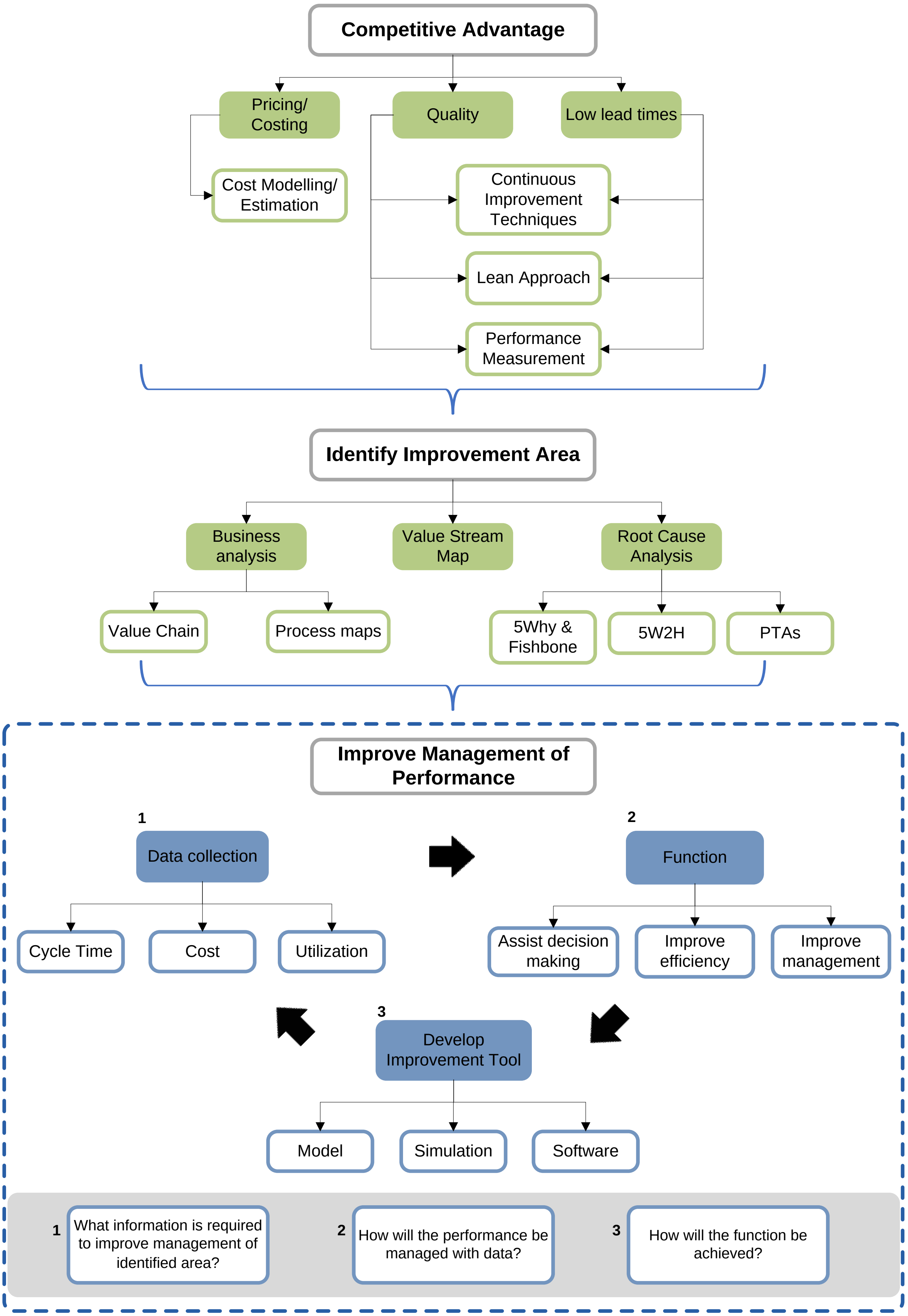


Figure 2: Generic approach for developing a tool to increase competitiveness

Approach abbreviations

5W2H	5W: What? Why? Where? Who? When?, and 2H: How? Question 2 times
PTA	Problem-Tree Analysis

Questionnaire

These questions will be used as validation that the developed approach in Figure 2 can be used for a South African manufacturing SME to improve its competitiveness. No personal information like name, age etc. will be used or distributed.

1.) What is your occupation description at your current company? Example consulting, project manager etc.

Company name:

Occupation:

1.) Do you have some experience in the manufacturing field?
Yes/No

2.) Have you ever had to implement improvements to increase competitiveness in a (your) company?
Yes/No

3.) Can the competitiveness of a manufacturing SME in SA be improved by using the approach presented in figure 2?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree

Why:

4.) Does the approach cover the necessary information to implement improvements in a manufacturing SME?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree

5.) Is there any other information that you would deem necessary for the approach to include, other than those presented?

Yes/No

What information:

6.) Is this approach generic for manufacturing SME's in South African context to increase competitiveness?

Yes/No

Why:

7.) Could you use this approach in your working environment?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree

8.) What from this approach have you used previously in your working environment?

9.) Has this approach introduced or informed you of something new that you would use in the future to implement improvement?

Yes/No

What part of approach:

10.) Could this approach possibly help you in future for implementing improvement ideas to increase the competitiveness of a company?

11.) General comments?

Thank You

Date:

____

Feedback Expert 1

1.) What is your occupation description at your current company? Example consulting, project manager etc.

Company name: GPS Food Group

Occupation: Operations Manager

2.) Do you have some experience in the manufacturing field?
Yes

3.) Have you ever had to implement improvements to increase competitiveness in a (your) company?
Yes

4.) Can the competitiveness of a manufacturing SME in SA be improved by using the approach presented in figure 2?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
x			

Why: The Model is based on continuous improvement basically covering the Plan-Do-Check and Act cycle. Data being collected is used for decision making and can also be used for the KPI dashboard in the future.

5.) Does the approach cover the necessary information to implement improvements in a manufacturing SME?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
	x		

6.) Is there any other information that you would deem necessary for the approach to include, other than those presented?

Yes

What information: Measuring the quality and performance of the raw material (Can be part of the Value Stream map). Biltong is made of meat. If the meat is not consistent in quality the experience of the consumer will be different no matter what you do. Selling is 50% of buying. The source of the raw meat or the method of purchase might be part of the competitive advantage? I will also make use of Current Reality Tree and FMEA.

7.) Is this approach generic for manufacturing SME's in South African context to increase competitiveness?

Yes

Why: The model covers the basics with several tools build into the model. I also think the model is easy to implement and to execute.

8.) Could you use this approach in your working environment?

1 Strongly Agree	**2 Agree**	**3 Disagree**	**4 Strongly disagree**
	x		

9.) What from this approach have you used previously in your working environment?

Root Cause analysis, using reliable data to make daily decision fast and accurate. Is very important to collect useful data which then get used to drive the main KPI's. Thus, identifying the main KPI's is very important to any business.

10.) Has this approach introduced or informed you of something new that you would use in the future to implement improvement?

Yes

What part of approach: The Function part

11.) Could this approach possibly help you in future for implementing improvement ideas to increase the competitiveness of a company?
YES

12.) General comments?
Well-developed model for any SME

Thank You

Date:

23/10/2018

Feedback Expert 2

1.) What is your occupation description at your current company? Example consulting, project manager etc.

Company name: Qmuzik Technologies

Occupation: Business Consultant

2.) Do you have some experience in the manufacturing field?
Yes

3.) Have you ever had to implement improvements to increase competitiveness in a (your) company?
No

4.) Can the competitiveness of a manufacturing SME in SA be improved by using the approach presented in figure 2?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
x			

Why: Figure 2 thoroughly explains the manufacturing process. All the bases seems to be covered. By moving through the process step-by-step and being able to see the business process in real time in order to recognise errors will definably give a company a competitive edge. The process explained does not only point out where to improve but also gives some guideline on how to improve.

5.) Does the approach cover the necessary information to implement improvements in a manufacturing SME?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
x			

6.) Is there any other information that you would deem necessary for the approach to include, other than those presented?

No

What information:

7.) Is this approach generic for manufacturing SME's in South African context to increase competitiveness?

Yes

Why: I can see the changes made from the case study approach to the generic approach. The case study used is a typical process of manufacturing. Another case study might also have been necessary to prove the generic approach.

8.) Could you use this approach in your working environment?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
x			

9.) What from this approach have you used previously in your working environment?

Working not just in the IT sector but also as a business consultant, we are constantly identifying and improving our client's businesses and indirectly improving their competitiveness. We also work with each of the described 'headings' subconsciously and not knowing or documenting each of the processes.

This process in Figure 2 will be greatly beneficial to manufacturing companies not having a business consultant or industrial engineer to help with continuous improvements and competitiveness.

10.) Has this approach introduced or informed you of something new that you would use in the future to implement improvement?

Yes

I will definitely use Figure 2 as a reference when wanting to implement improvements because it is a great guideline of where to start and what to do next. It can also be used as a benchmark of measuring your previous data to the next.

11.) Could this approach possibly help you in future for implementing improvement ideas to increase the competitiveness of a company?

Yes, this approach will also be greatly beneficial for top management to quickly evaluate where they are and where they are moving to. Give a great overview of how to approach implementations and improve competitiveness.

12.) General comments?

Thank You

Date:

23-10-2018

Feedback Expert 3

1.) What is your occupation description at your current company? Example consulting, project manager etc.

Company name: EY Namibia

Occupation: Performance Improvement Consultant

2.) Do you have some experience in the manufacturing field?
Yes

3.) Have you ever had to implement improvements to increase competitiveness in a (your) company?
Not in the company I work for but for our clients yes.

4.) Can the competitiveness of a manufacturing SME in SA be improved by using the approach presented in figure 2?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
X			

Why:

My experience has shown that data collection is crucial to developing useful analysis, especially so for the use of performance improvement. One thing our clients almost always have a problem with is clean and appropriate data collection mechanisms across the whole company. And once this is in order one can derive very useful conclusions to what the company needs and where to improve.

This model is simple to follow and can have great impact.

5.) Does the approach cover the necessary information to implement improvements in a manufacturing SME?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
x			

6.) Is there any other information that you would deem necessary for the approach to include, other than those presented?

None

What information: The approach is generic enough to be applied to a wide range of SMEs and adding more might jeopardise this.

7.) Is this approach generic for manufacturing SME's in South African context to increase competitiveness?

Yes

Why: I feel this can be applied to a wide range of manufacturing SME's, and with little alterations, it can work in other business environments too.

8.) Could you use this approach in your working environment?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
	X		

9.) What from this approach have you used previously in your working environment?

The 'Improve Management of Performance' stage was crucial at one of our clients which operates in the copper smelting industry. The client had poor data collection and maintenance which was a crucial part to fix before any further improvements could commence.

10.) Has this approach introduced or informed you of something new that you would use in the future to implement improvement?

No

What part of approach: I have often come across similar approaches in my working environment but it was always detached i.e. I have applied various parts of this approach but have not yet applied it as a whole. Thus, this framework can prove very useful.

11.) Could this approach possibly help you in future for implementing improvement ideas to increase the competitiveness of a company?

Definitely.

12.) General comments?

This approach is quite thorough yet generic. I believe this can be applied to a wide range of areas.

Thank You

Date:

5/10/2018

Feedback Expert 4

1.) What is your occupation description at your current company? Example consulting, project manager etc.

Company name: AC Industries (Medispec, BA Coatings, Machine Innovations, Leron Castings, Bunker Hills)

Occupation: Owner/Director of all

2.) Do you have some experience in the manufacturing field?
Yes/No Yes (Quite a lot!)

3.) Have you ever had to implement improvements to increase competitiveness in a (your) company?
Yes/No Yes, many (probably more than a 1000) times.

4.) Can the competitiveness of a manufacturing SME in SA be improved by using the approach presented in figure 2?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
	Agree		

Why: In practice it is seldom as "formal" as figure 2. Time is always of essence and the quickest way of fixing the problem is to work backward from the bottle necks or problem areas.

5.) Does the approach cover the necessary information to implement improvements in a manufacturing SME?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
	Agree		

Again, a similar answer as above.

6.) Is there any other information that you would deem necessary for the approach to include, other than those presented?

Yes/No No

What information:

7.) Is this approach generic for manufacturing SME's in South African context to increase competitiveness?

Yes/No (Yes and no)

Why: Competitiveness will not be changed by implementing "formal" procedures in SME's. Competitiveness is a culture of a nation and have to be fixed from the bottom to the top. Starting

at all the simple things, a proper school system, proper training institutions, proper work ethics, a government that incentivise excellence.

8.) Could you use this approach in your working environment?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
		Disagree	

9.) What from this approach have you used previously in your working environment?

My situation is quite different to this example. My emphasis is on proper research, both cost and price structure, acquiring the best technology affordable, technical edge.

10.) Has this approach introduced or informed you of something new that you would use in the future to implement improvement?

Yes/No No

What part of approach: I have been probably too long in business to trust any other "system" than what I have proven to myself. This tree analysis could work for a newcomer in business that need a lot of support. I have built six companies over 30 years, and I am a trained engineer which are seldomly good businessmen. I had to develop my own problem-solving processes, which is far from the typical mainstream trained business people. At the end of my career, maybe my approach was the better approach given the results?!

11.) Could this approach possibly help you in future for implementing improvement ideas to increase the competitiveness of a company?

No (Sorry)

12.) General comments?

No (Sorry)

Thank You

Date:

29 October 2018

Feedback Expert 5

1.) What is your occupation description at your current company? Example consulting, project manager etc.

Company name: Sumit Insights

Occupation: Consultant Business Analyst

2.) Do you have some experience in the manufacturing field?
Yes

3.) Have you ever had to implement improvements to increase competitiveness in a (your) company?
Yes

4.) Can the competitiveness of a manufacturing SME in SA be improved by using the approach presented in figure 2?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
	X		

Why:

In standardised products, a company can improve market share by being more effective with resources. However, I have seen companies that create value through new and innovative products perform better than purely cutting costs and improving production.

5.) Does the approach cover the necessary information to implement improvements in a manufacturing SME?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
	X		

6.) Is there any other information that you would deem necessary for the approach to include, other than those presented?

Yes

What information:

Under "Data Collection" I would add technology / data collection tools. This can speed up the process that follows. Too often companies can not proceed due to a lack of valuable accurate and available data!

7.) Is this approach generic for manufacturing SME's in South African context to increase competitiveness?

No

Why:

Most SME's in RSA do not have adequate data collection tools and as such miss out on efficiencies that could be gained through Industry 4.0 technologies.

8.) Could you use this approach in your working environment?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
X			

9.) What from this approach have you used previously in your working environment?

All of it

10.) Has this approach introduced or informed you of something new that you would use in the future to implement improvement?

No

What part of approach:

I use these techniques as a basis for most of my work with clients (not always together as suggested above).

11.) Could this approach possibly help you in future for implementing improvement ideas to increase the competitiveness of a company?

Yes!

12.) General comments?

I would place a greater emphasis on data collection tools. The implementation of credible, useable systems as well as the training of staff to use the tools appropriately. Without the basic systems in place, very little value can be derived from the data (GIGO).

Thank You

Date:

29 October 2018

Feedback Expert 6

1.) What is your occupation description at your current company? Example consulting, project manager etc.

Company name: Zibo Containers

Occupation: Production manager

2.) Do you have some experience in the manufacturing field?
Yes

3.) Have you ever had to implement improvements to increase competitiveness in a (your) company?
Yes

4.) Can the competitiveness of a manufacturing SME in SA be improved by using the approach presented in figure 2?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
	X		

Why: I agree. You need to start with data in order to make decisions. From the data you should devise an implementation procedure. Your step 2 and 3. I assume going back to step 1 would include the review of how effective step 2 and 3 was.

I believe data from the market also plays a part in Improve management of performance, which effects your competitiveness.

5.) Does the approach cover the necessary information to implement improvements in a manufacturing SME?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
X			

6.) Is there any other information that you would deem necessary for the approach to include, other than those presented?

Yes

What information: Market/industry specific related data.

7.) Is this approach generic for manufacturing SME's in South African context to increase competitiveness?

Yes

Why: This is a continues improvement cycle irrespective of the industry.

8.) Could you use this approach in your working environment?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
	X		

9.) What from this approach have you used previously in your working environment?

We currently have step 1 and 2 in place. Our step three is implementation, which can be investment or changing how a task is done in order to be more efficient. This mostly start with a demo before full implementation. Figure.2 step 3 is something we can work towards.

10.) Has this approach introduced or informed you of something new that you would use in the future to implement improvement?

Yes

What part of approach: Step 3, simulation.

11.) Could this approach possibly help you in future for implementing improvement ideas to increase the competitiveness of a company?

Yes, this will give more support towards calculated risks.

12.) General comments?

Non

Thank You

Date:

07/11/2018

Feedback Expert 7

1.) What is your occupation description at your current company? Example consulting, project manager etc.

Company name: Absolute Ablutions

Occupation: Production manager

2.) Do you have some experience in the manufacturing field?
Yes

3.) Have you ever had to implement improvements to increase competitiveness in a (your) company?
Yes

4.) Can the competitiveness of a manufacturing SME in SA be improved by using the approach presented in figure 2?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
	X		

Why:

By acquiring data one can identify problem areas which can be improved upon using the necessary tools. Higher efficiency and better quality will lead to greater competitiveness.

5.) Does the approach cover the necessary information to implement improvements in a manufacturing SME?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
		X	

6.) Is there any other information that you would deem necessary for the approach to include, other than those presented?

Yes

What information:

What are the limits to the scope of the solution? Such as initial cost.

7.) Is this approach generic for manufacturing SME's in South African context to increase competitiveness?

Yes

Why:

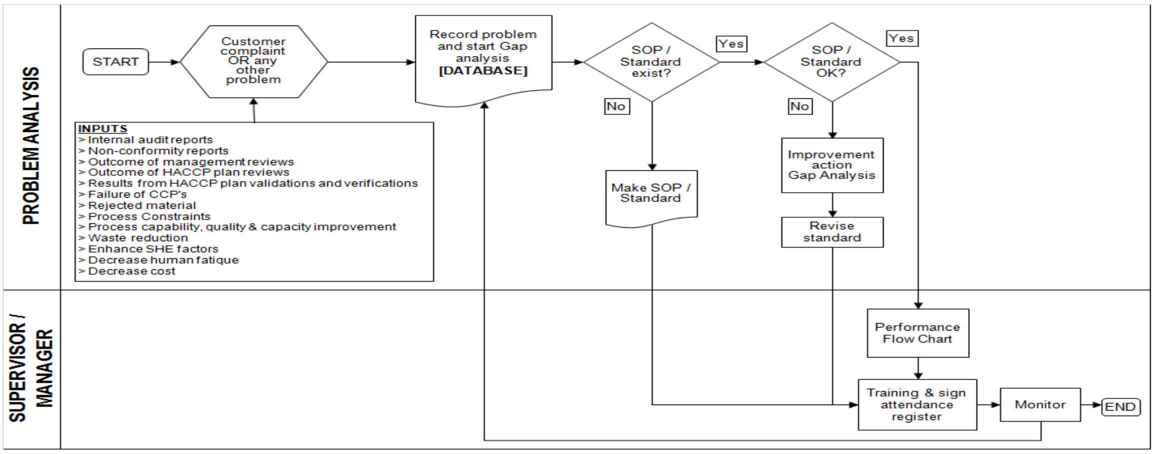
So far as I can think this can be applied to most SME's in South Africa.

8.) Could you use this approach in your working environment?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
X			

9.) What from this approach have you used previously in your working environment?

The framework I use in my working environment are presented below and has similar aspects that are addressed in the approach, in figure 2.



10.) Has this approach introduced or informed you of something new that you would use in the future to implement improvement?

Yes

What part of approach:

The important part is to gather data before looking for a solution right away.

11.) Could this approach possibly help you in future for implementing improvement ideas to increase the competitiveness of a company?

The implementation part is tailored for every company, so I don't believe an approach can very much assist with that. But in a broad sense the approach will still aid a company in the right direction by starting with asking the right questions.

12.) General comments?

This approach is well thought through and is certainly something any manager should have stuck to his/her wall to be reminded of.

Thank You

Date:

08/11/2018

Feedback Expert 8

1.) What is your occupation description at your current company? Example consulting, project manager etc.

Company name: Biltong Factory

Occupation: Owner/Director

2.) Do you have some experience in the manufacturing field?
Yes 16 years

3.) Have you ever had to implement improvements to increase competitiveness in a (your) company?
Yes continuously

4.) Can the competitiveness of a manufacturing SME in SA be improved by using the approach presented in figure 2?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
Yes			

Why: Better planning and increased volumes with less labour equal's higher productivity and saving costs.

5.) Does the approach cover the necessary information to implement improvements in a manufacturing SME?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
Yes			

6.) Is there any other information that you would deem necessary for the approach to include, other than those presented?

No

What information:

7.) Is this approach generic for manufacturing SME's in South African context to increase competitiveness?

Yes

Why: With increasing production cost any manufacturing company needs to work better and smarter to stay competitive.

8.) Could you use this approach in your working environment?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
Yes			

9.) What from this approach have you used previously in your working environment?

Most of our daily production planning was done on past experience and lessons learned from the past. This approach gave us some more accurate options and we could make the best financial decision.

10.) Has this approach introduced or informed you of something new that you would use in the future to implement improvement?

Yes

What part of approach: We have used this approach to change our production lines, invest in better manufacturing machinery and implementing better production schedules.

11.) Could this approach possibly help you in future for implementing improvement ideas to increase the competitiveness of a company?

Yes. This approach helped us to look at other areas in our company to improve cost savings and be more competitive.

12.) General comments?

As a business owner I realise the importance of having access to such an approach.

It helped our company to increase production, save on overtime and bring our input cost down.

The result is better profits and being more competitive in our market.

Thank You

Date:

09/11/2018 ____________

Feedback Expert 9

1.) What is your occupation description at your current company? Example consulting, project manager etc.

Company name: Roos Family Vineyards Pty Ltd

Occupation: Consultant/Logistics Manager

2.) Do you have some experience in the manufacturing field?
Yes

3.) Have you ever had to implement improvements to increase competitiveness in a (your) company?
Yes

4.) Can the competitiveness of a manufacturing SME in SA be improved by using the approach presented in figure 2?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
X			

Why:

I fully agree that the first step should be to analyse the company's competitive advantages. This also ensures a well balanced strategy, as it considers both internal factors (such as production costs) and external factors (such as lead times).

In my experience, not enough relevant data is being captured in most South African SME's, which is why I agree that accurate and relevant data collection should be the first step in the improvement process.

5.) Does the approach cover the necessary information to implement improvements in a manufacturing SME?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
	X		

6.) Is there any other information that you would deem necessary for the approach to include, other than those presented?

Yes

What information:

The only thing I might consider adding is a reference to existing best practices in step 3 of the improvement process. Eg the SCOR model has an extensive list of best practices which might help create the improvement tool.

7.) Is this approach generic for manufacturing SME's in South African context to increase competitiveness?

Yes

Why: It is up to the company to define their competitive advantages within their specific industry. Thereafter the model is generic enough to accommodate different supply chains.

8.) Could you use this approach in your working environment?

1 Strongly Agree	2 Agree	3 Disagree	4 Strongly disagree
X			

9.) What from this approach have you used previously in your working environment?

The process of starting with a competitive advantage analysis and drilling down to identify specific processes which need improvement.

10.) Has this approach introduced or informed you of something new that you would use in the future to implement improvement?

Yes/No

What part of approach:

The only thing which I have not yet done is a complete VSM.

11.) Could this approach possibly help you in future for implementing improvement ideas to increase the competitiveness of a company?

Yes. It effectively ties excising techniques (lean approach, VSM, etc) into a single top-down improvement strategy.

12.) General comments?

Thank You

Date:

9/11/2018