UNIVERSITY OF KWAZULU-NATAL

APPLYING LEAN PRINCIPLES IN CRAFT BREWING TO IMPROVE QUALITY AND REDUCE COSTS: TWO KWAZULU-NATAL CASE STUDIES

By

Sindisiwe Mahlangu

212545122

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Supervisor: Dr RH Salisbury

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DECLARATION

I Sindisiwe Mahlangu, declare that

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Firstly, I would like to thank God Almighty, it is all because of you Lord!

Writing this thesis has been fascinating and extremely rewarding. I would like to express my sincere and deepest gratitude to my supervisor, Dr RH Salisbury, who ploughed through several preliminary versions of my text, making critical suggestions and posing challenging questions. His expertise, invaluable guidance, constant encouragement, affectionate attitude, understanding, patience and healthy criticism added considerably to my experience. Without his continual inspiration, it would not have been possible to complete this study.

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DEDICATION

For mum and dad, who have always loved me unconditionally and whose good examples have taught me to work hard for the things that I aspire to achieve.

ABSTRACT

A significant number of companies around the world have implemented lean methodologies in order to remain competitive. Although these were initially developed for large manufacturing companies, the principles that serve as a foundation for these methodologies are, arguably, also applicable to small companies. The proposed research will focus on small craft breweries in the KwaZulu-Natal province of South Africa to determine if they too can benefit from implementing practices that are based on lean principles.

The world's craft brewing industry is well-established and growing rapidly. Most of the beer brewed in South Africa is mass-produced at comparatively low cost. Craft beer brewed by smaller scale breweries is relatively more expensive to produce and consumers have to accept trade-offs between the perceived better quality and higher cost of craft beer. In order to gain and maintain market share, craft brewers need to produce quality beer whilst reducing production costs.

The objectives of this study were threefold. Firstly, it sought to identify appropriate assessment tools that may be used to measure waste in craft breweries. Secondly, to identify and measure any sources of waste that may occur in craft breweries. Lastly, to determine if and how craft brewers can introduce lean methodologies based on lean principles in their production processes in order to improve quality and reduce costs.

The study was guided by lean theory. The principles derived from this directed the deployment of lean tools and practices to implement lean production methodologies. Lean theory argues that lean methodologies, if implemented correctly, will yield positive results for all firms in all industries.

A multi-case study approach was used, supported by five data collection instruments; direct observations, participant observations, documents & records and semi-structured interviews. A convergent, parallel, mixed methods design was used as this allowed both qualitative and quantitative data to be gathered, analysed and then merged to interpret the findings and results. The data was analysed using content analysis with NVivo software.

The main findings of this study indicate that:

1. Lean tools, like the Lean Assessment Tool, which consists of several lean improvement programmes and tools (*e.g. setup time reduction, visual controls*) may be used to assess waste in craft breweries.
2. The sources of wastes and inefficiencies which were identified from the case studies relate to inventory, overproduction, waiting time, unnecessary transporting, processing waste, inefficient work methods, product defects and underutilised human resources.
3. Identifying lean tools and programmes that the company can implement under its current production capabilities is a key success factor in becoming a lean organisation.
4. Having a step by step implementation model which is clear to follow will help companies to implement lean production.
5. To produce good quality beer, the ingredients used must be of good quality. Also, close monitoring of the brewing processes, times and temperatures is essential.
6. The current challenges in the craft beer industry include high levels of competition from the mainstream beer producing giants, distribution problems, maintaining consistent quality and developing effective marketing plans in a highly contested market.

The study was concluded by discussing the implications of these findings for theory and literature, as well as for practitioners. Recommendations, specific for these case studies were provided and areas for future research suggested.

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CHAPTER ONE: INTRODUCTION

1.1 Introduction

Beer is the third most common beverage in the world after water and tea and is made from four essential ingredients: water, hops, malted cereal grain and yeast (Bleier, Callahan, Farmer, & Min, 2013; Bisht, 2015). For thousands of years, brewing was an art practised in the home or by brewers who served their local communities. Over the last fifty years, beer production became concentrated in the hands of large brewers and by 2015, approximately 69% of beer sold was produced by three companies; AB InBev, SABMiller and Heineken (see Figure 1.1).

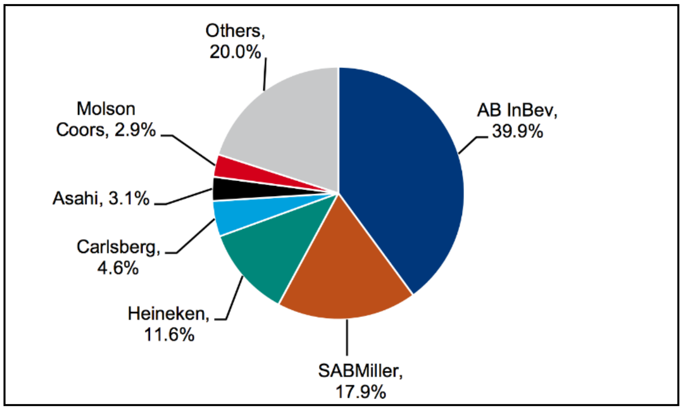


Figure 1. 1 Beer Industry Market Share Pie Chart

Source: *(Holodny, 2015)*

Prior to its acquisition by AB InBev in October 2016, South African Breweries-Miller (SABMiller) produced about 90% of the beer consumed in South Africa (Green, 2015). This merger of the world's two largest brewers has created a "megabrewer" with unprecedented control over the international beer industry (Powell, 2015; Daneshkhu, 2016).

In spite of the domination of the industry by a few large companies there has been a global increase in the popularity of craft beer in the last few decades (Donadini & Porretta, 2017). The craft beer industry comprises small breweries that are typically independent and employ traditional production methods (Green, 2015; Grunde, Siqi, & Merl, 2014). The craft beer phenomenon dates its origins in the United States, in the 1970s and by the 1990s, it had spread to other markets. The exponential growth of the craft beer market has been supported by the existing structure of the beer industry, whose model has allowed craft brewers to find niche markets and experiment with different flavours and tastes for different consumers (Donadini & Porretta, 2017).

The South African craft beer industry is expanding rapidly as a result of changing consumer tastes and a growing preference for locally produced foodstuffs. Analysts estimated that the industry would account for about 2.1% of the total market in South Africa by 2017, representing a 700% increase from 2011 (SA Food Review, 2015).

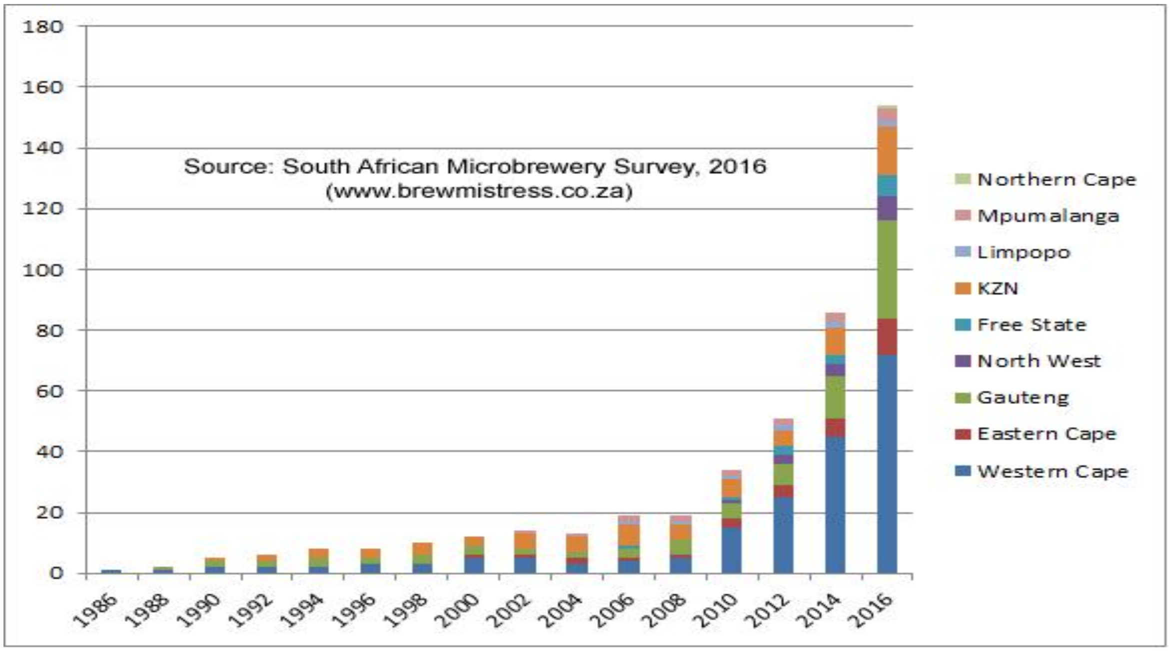


Figure 1. 2 South African Craft Beer Statistics

Source: *(Corne, 2017)*

The figure above shows the number of craft breweries spread across the provinces in South Africa. The number of craft breweries increased from an estimated 156 in 2016 to approximately 217 in 2017 (Corne, 2017; Craftbru, 2017). Corne further points out that it is difficult to get the correct craft beer statistics in South Africa due to a lack of cooperation from some of the craft brewers. Also, since there are no official statistics available, the figures provided are only estimates.

1.2 Background of the study

Craft breweries in South Africa have to compete with giants that have ample resources for marketing, sourcing cheaper ingredients, and for the purchase of sophisticated equipment (Powell, 2015). Craft beer is more expensive to make than mass produced beer since small breweries lack these scale economies (Brooks, 2011; Brown, 2016). The process is more labour intensive and the product usually has a shorter shelf life since it is unfiltered and unpasteurised (Donadini & Porretta, 2017).

Lean production is a management approach that was developed from the Toyota Production System (TPS) (Stevenson, 2012; Schmidtke, Heiser, & Hinrichsen, 2014). It integrates human activity and the operation of machines to eliminate waste and manage the variability that occurs in internal processes as well as activities of suppliers and customers (Mostafa, Dumrak, & Soltan, 2013; Saurin, Rooke, & Koskela, 2013). Although lean production was developed for large-scale manufacturing enterprises, there is an increasing interest in its application in Small and Medium-sized Enterprises (SMEs) (Hu, Mason, Williams, & Found, 2015).

Lean production requires a company-wide approach and lean principles have been developed as guidelines for this process. Furthermore, lean practices (such as Just-in-Time) provide the frameworks for lean implementation, with lean tools and techniques providing the day-to-day methods that apply to lean specific processes.

This study explored the potential for small, independent craft breweries to improve quality and reduce costs through the implementation of lean production processes.

1.3 Research problem

With increasing competition in the beer industry, specifically in the craft brewing industry, coupled with an increasing number of new entrants in this industry, the quality of the beer and the reduction of the cost of production will be the focus areas for craft brewers to compete within the beer industry. Production methodologies, like lean production, have been implemented worldwide and in different industries in order to decrease waste and improve quality. The identification and reduction of operational waste lowers the cost of production and improves the quality. However, the numerous tools and techniques of lean production cannot all be implemented by an SME such as a craft brewery in order to improve quality and reduce costs because small businesses typically have limited resources and thus cannot afford the more expensive interventions (Rose, Deros, & Rahman, 2010). In addition, not all the tools and techniques are universally applicable to all industries Deflorin & Scherrer-Rathje, (2012).

Lean implementation in South African industries is still fairly new and a significant amount of the research being carried out in South Africa focuses on the development of frameworks, models and the application of basic lean tools. On the other hand, some research, for example, lean production in the German industries, focuses on tailor suiting lean tools to specifically fit its local industries (Dondofema, Matope, & Akdogan, 2017).

This study will address the problem of selecting the right lean elements in a craft brewery so as to reduce costs and improve quality and how to implement these elements.

The proposed research will focus on the craft brewing industry in South Africa in order to develop guidelines for a lean craft brewery. Using case studies, it will identify any waste which may exist in the breweries studied, and then suggest how these wastes can be eliminated using lean practices such as value stream mapping and visual controls. Finally, the study will suggest how these can be implemented to reduce costs and improve quality.

1.4 Research questions

This research sought to answer the following questions:

1. What tools can be used to assess waste in craft breweries?
2. What wastes occur in craft breweries?
3. Are lean principles appropriate for application in craft breweries and if so, how can craft brewers introduce lean principles in their production processes to improve quality and reduce costs?

1.5 Contribution of the research

This research contributes to the theory of lean production in SMEs by taking a holistic view of these organisations and their supply chains. In particular, it is a contribution to small food and drink manufactures. Specifically, the research tested the applicability of the lean production tools and techniques in craft breweries.

On a practical level, this research aims to provide an industry-specific set of guidelines that small brewers can use to increase the profitability of their operations. SMEs are an essential part of the South African economy and craft brewers are an example of locally-focused enterprises with the potential to create jobs and contribute to socio-economic development.

1.6 Justification for the research

This study should be conducted because SMEs are still under-researched in the field of lean management (Majava & Ojanpera, 2017) and yet these organisations are the backbone of the economy and deserve more attention (Robu, 2013). Without this study, SMEs in general, and South African craft breweries in particular will be poorly served in terms of academic attention and will lack practical guidelines for the implementation of a production system that could potentially ensure their survival in a highly competitive environment.

1.7 Overview of the methodology

A multi-case study approach was used, supported by five data collection instruments; semi-structured interviews, direct observations, participant observation, documentation and archival records. A convergent, parallel, mixed methods design was used as this allowed both qualitative and quantitative data to be gathered and analysed and then merged to interpret the findings and results. The qualitative data collected were analysed using content analysis with NVivo software.

1.8 Limitations of study

A limitation of the proposed research is that the investigation was confined to two craft breweries, which may not be fully representative of the craft brewery industry in South Africa. A further potential limitation was that not all required information would be forthcoming from the case breweries and certain gaps in the data may occur as a result.

1.9 Definition of key terminology

The following section defines how key terms were used in this study.

a) Brewery – A firm that produces and sells beer

b) Craft beer - A beer that is made in a traditional or non-mechanised way by a small brewery

c) Craft brewery – A small, typically independent brewery, that makes beer using more traditional methods

d) Lean production - An approach to management that focuses on cutting out waste, whilst ensuring quality

e) Waste - Any expense or effort that is put forward which does not transform raw materials into an item the customer is willing to pay

1.10 Organisation of the dissertation

This chapter provided the overall view of the study; the background, research questions, justification, and significance of the study as well as a brief methodology of how the data was collected and analysed. The remainder of this dissertation is organised into the following chapters, providing a research map at the beginning of each chapter.

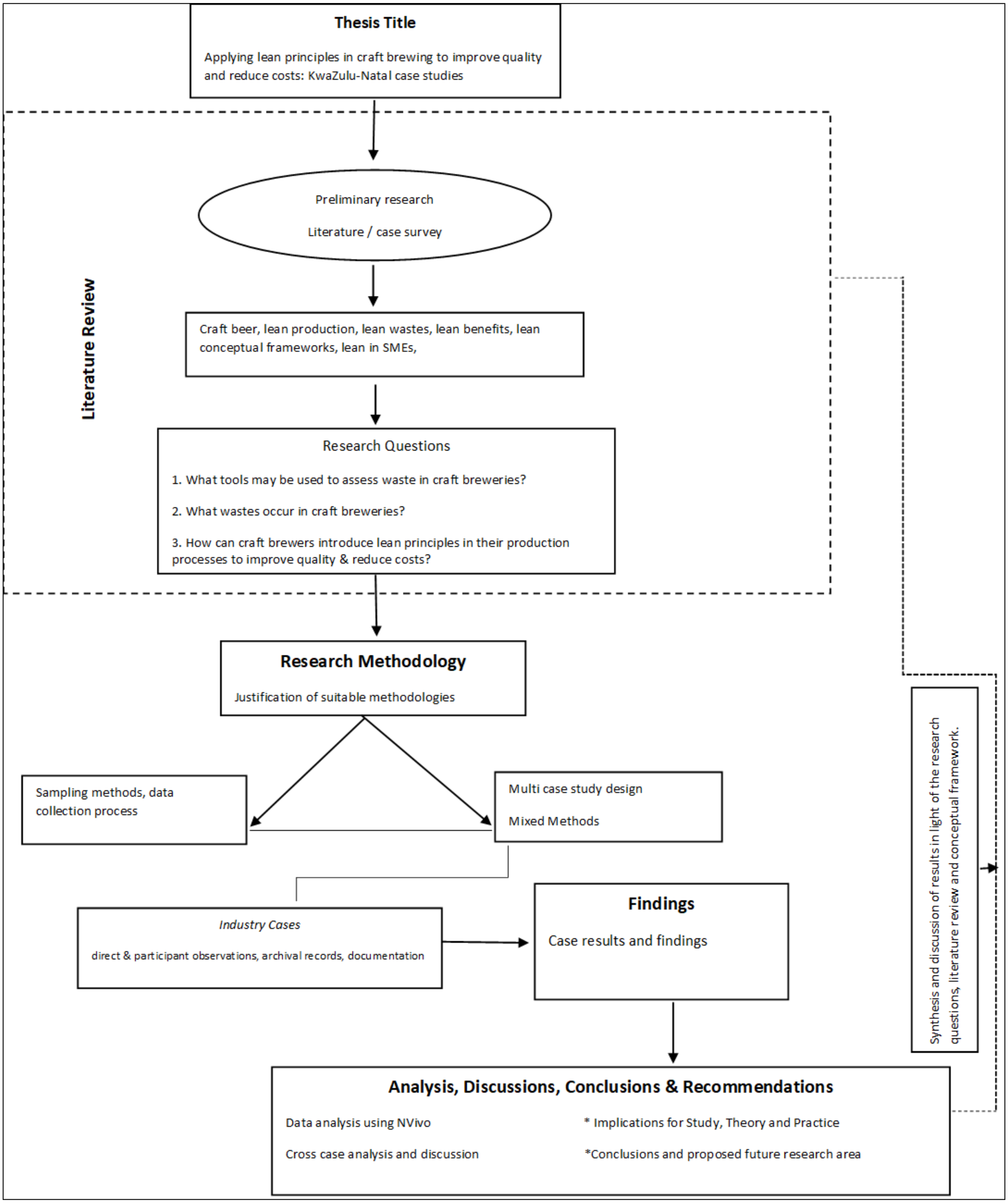
Chapter 2 – This chapter examines the literature of the lean production framework, with particular reference to its implementation in SMEs and discusses the conceptual framework adopted for this research.

Chapter 3 – This chapter discusses the research approach and the research methods used to achieve the objectives of this study. It describes the participants, research design, data collection instruments and procedures that were used.

Chapter 4 – The chapter presents the findings and results of an empirical investigation of the case study breweries.

Chapter 5 – This chapter provides a discussion of the findings and results. It also provides the implications of the findings and results for this study, for theory, and for practice. Lastly, it states the contribution of this research as well as the limitations of this study.

Chapter 6 - This chapter summaries and concludes the dissertation. It also provides recommendations and suggests areas for future research.


Thesis Title
Applying lean principles in craft brewing to improve quality and reduce costs: KwaZulu-Natal case studies
Literature Review
Preliminary research
Literature / case survey
Craft beer, lean production, lean wastes, lean benefits, lean conceptual frameworks, lean in SMEs,
Research Questions
1. What tools may be used to assess waste in craft breweries?
2. What wastes occur in craft breweries?
3. How can craft brewers introduce lean principles in their production processes to improve quality & reduce costs?
Research Methodology
Justification of suitable methodologies
Sampling methods, data collection process
Multi case study design
Mixed Methods
Industry Cases
direct & participant observations, archival records, documentation
Findings
Case results and findings
Synthesis and discussion of results in light of the research questions, literature review and conceptual framework.
Analysis, Discussions, Conclusions & Recommendations
Data analysis using NVivo
Cross case analysis and discussion
* Implications for Study, Theory and Practice
*Conclusions and proposed future research area

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Chapter one introduced the study and provided the overall research objectives of this study. It also provided the justification as well as the contribution of this study.

Many studies have been carried out testing, applying and implementing lean production methodologies and theories. Whilst the literature covers a wide range of these topics, this chapter reviews the literature on lean production and examines it with particular reference to its implementation in SMEs. The following literature review diagram, Figure 2.1, shows how all the relevant variables and themes for this study are linked together.

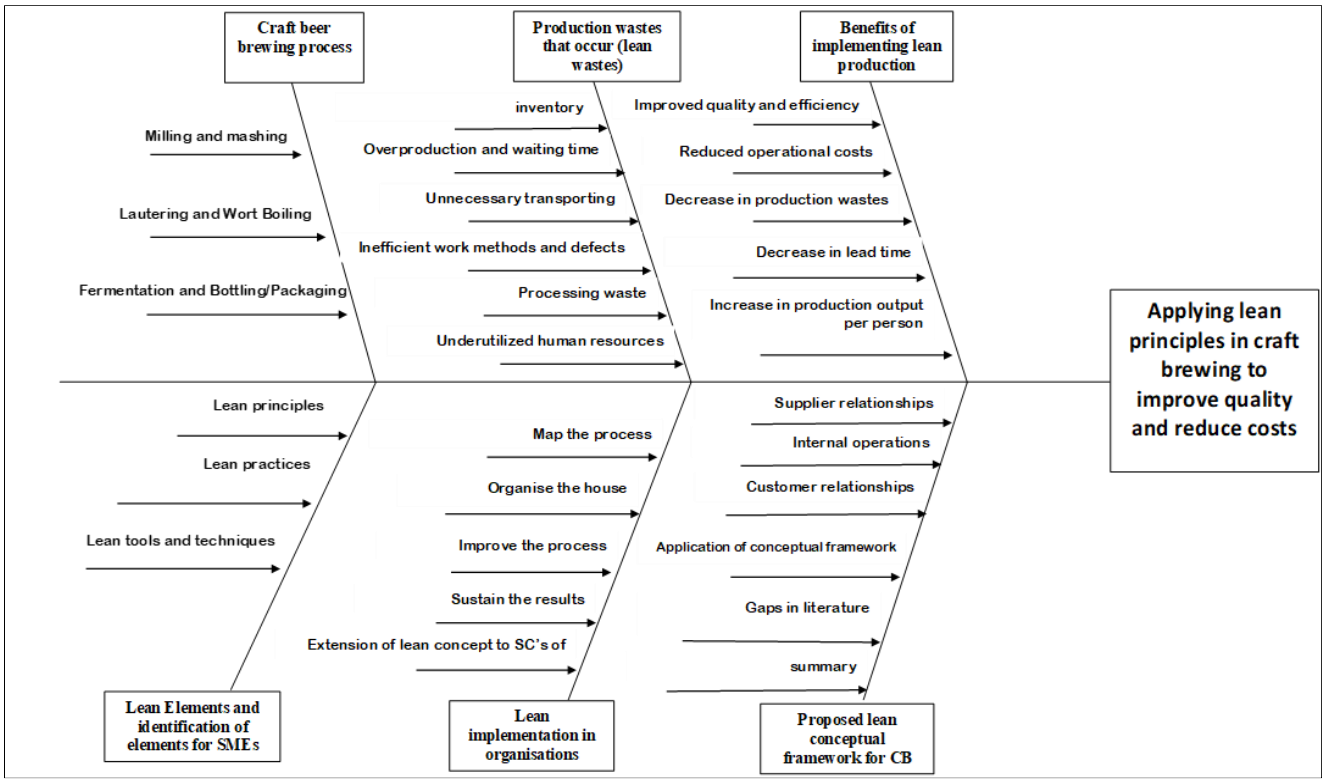


Figure 2. 1 Literature Review Links

Firstly, the craft brewing production process is described. This provides an understanding of how resources flow during production and the order of the process steps that take place. A discussion of lean waste is provided to be able to identify if any of these wastes occur during the brewing process that is discussed.

The benefits of implementing production methodologies, in particular lean methodologies are discussed. A further discussion is provided on lean production in small and medium enterprises, with reference to small businesses in the food and drinks manufacturing sector. Lean practices, tool and techniques that are applicable to SMEs, are reviewed. Finally, the proposed lean conceptual framework is discussed.

2.2 Craft Beer Production

Beer is made from four essential ingredients; hops, malted cereal grain, yeast and water (Bleier, Callahan, Farmer, & Min, 2013; Bisht, 2015). For every one litre of beer made, 8-14 litres of water are needed (Fagan, 2015). Craft beer production can be broken down into three transformation activities; pre-fermentation, fermentation, and post-fermentation comprising the six processes of milling, mashing, lautering, wort boiling, fermentation and packaging (Banda, Matumba, & Mondliwa, 2015; Bleier, et al., 2013), as depicted in Figure 2.2 and described in the following sections.

Milling → Mashing → Lautering → Wort Boiling → Fermentation → Packaging

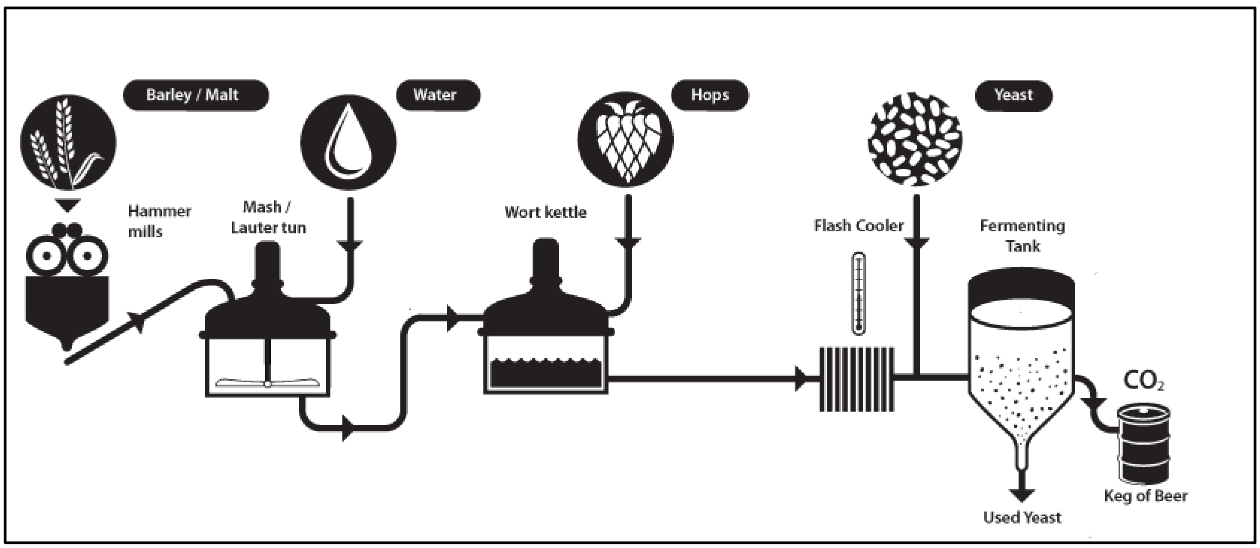


Figure 2. 2 Beer Production Process

Source: *(Blackhorse, 2017)*

2.2.1 Milling

Beer is produced in batches. Most brewers do not malt their own grain but purchase cereal grains that have already gone through the malting process (Olajire, 2012). Most brewers use barley malt, although other cereals may be used, for example, wheat, rye, oats, millet, and sorghum (Briggs, et al., 2004). Different types of speciality malts are used for different recipes or brews. The malt is cracked open and crushed until it becomes a coarse powder, which is known as grist. The grist is sent into a mash tun or mash conversion vessel (Olajire, 2012; Bleier, et al., 2013; Banda, et al., 2015).

At the start of each brew, the malt (i.e. the malted cereal grains) is taken from the storage area to the brewery. The malt is milled in a dry or wet milling process. If a dry milling process is used, the grist is crushed in the mill rollers and sent to the mash tun. The advantages of using the dry process are that it is simple and cheaper to use, and a potential disadvantage of this process is that it produces a lot of dust and may possibly cause an explosion due to the ignition of dust sparks (Buttrick, 2017). Wet milling on the other hand does not produce dust and therefore no chances of an explosion. The wet milling process ensures that the grist case of the malted grains remains intact because it is moistened, unlike with dry milling, where there is a possibility of the malt being crushed to an extent that the grist case becomes fragmented or split, affecting the quality of the beer. However, the machinery required for the wet milling process is very expensive (Buttrick, 2017; Briggs, Boulton, Brook, & Stevens, 2004).

2.2.2 Mashing

During this process, the crushed malt (grist) and hot water are combined to extract the fermentable sugars from the crushed malt, forming sugar-saturated water known as wort (Olajire, 2012; Bleier, et al., 2013; Banda, et al., 2015).

Mash tun adjuncts (e.g. rice flakes, sugar) are sometimes added during the mashing process to reduce the cost of production by reducing the amount of malt required. They also may be used to add a different flavour. These adjuncts are added during mashing. However, this changes the characteristics of the beer. In some countries, the use of adjuncts is not allowed. For example, in Germany beer is strictly made from water, malt, hops and yeast (Briggs, et al., 2004).

The ideal hot water temperature for mashing is between 71-82 ºC. It is important to maintain the right temperatures because certain enzymes work best at certain temperatures. Failure to do this may lead to quality problems (Briggs, et al., 2004; Olajire, 2012).

The mashing process is energy intensive, with high levels of fuel being consumed at this stage. The spent grain that remains in the mash tun can be used as animal feed or may be used as fertilizer (Briggs, et al., 2004; Olajire, 2012).

2.2.3 Lautering

After mashing, the wort is pumped into a large vessel known as a lauter tun, where the wort is filtered or separated from the grain. The mash settles on the slotted deck or false bottom of the lauter tun. The wort then flows through the filter bed created by the mash residue and is run off into the kettle. Water is sprayed over the grain in the sparging process, to further increase the sugar extraction from the wort (Banda, et al., 2015; Bleier, et al., 2013; Olajire, 2012).

The lauter tun can be automated or manually operated. Most craft brewers use a manual tun because it is less expensive. The operational functions or processes in the lauter tun include (Briggs, et al., 2004):

- Warming the vessel or lauter tun and filling the under-deck space with water at approximately 75-78 ºC.
- Transferring the mash from the mash tun to the lauter tun. Some systems load the wort from above but transfer from the sides through. several ports is preferable.
- Three layers form in the lauter tun, sometimes known by their German names:
  Layer 1 (*Unterteig)* – consists of large and thick solids, which represent the under-processed mash that is rich in starch (Boulton, 2013)
  Layer 2 (*Hauptteig)* – consists of the grains which settle during the lautering operation (Boulton, 2013).
- Layer 3 (*Oberteig)* –consists of fine particles (Boulton, 2013). The wort passes through these layers which act as a filter and is re-circulated back to the lauter tun until it becomes clear.
- When the wort becomes clear, it is then diverted away from the lauter tun to the kettle

2.2.4 Wort Boiling

The clear, sweet wort is heated and sterilised in a brewing kettle. During this wort boiling stage, hops are added. Hops are added at different times throughout the boil to add complexity or density to the beer. When a regular boil of the wort is reached, the first hops are added as a preservative and also as a bittering agent, to balance the sweetness of the wort and are usually boiled for around sixty minutes. The second hops are added for flavouring, typically fifteen to thirty minutes before the end of the boil. A third set of aroma hops might be added during the last five minutes, to replace the oil properties that are lost during the boiling stage (Briggs, et al., 2004). Other flavours and colour may also be added at this boiling stage (Olajire, 2012). Adjuncts, for example, sucrose syrup, honey or sugar, are sometimes added into the kettle to increase the alcohol level of the beer. The boiling process takes one to two hours and is also energy intensive, using almost half of all the energy consumed in the brewing process (Briggs, et al., 2004). Spent hops and any other impure solids are separated from this wort, with these allowed to settle at the bottom so that the clear wort can be drained off (Banda, et al., 2015; Bleier, et al., 2013).

2.2.5 Fermentation

The wort is then cooled down using a heat exchanger and sent to the fermentation tank. In the heat exchanger, cold water flows through in one direction and the hot wort in the other direction to cool down the wort. Yeast is then introduced. During fermentation, the yeast metabolizes the sugars dissolved in the wort (Briggs, et al., 2004; Olajire, 2012).

The time taken for fermentation will depend on the type of beer that is being made, e.g. ale or lager. Yeast releases heat when it ferments, hence it is important for the brewer to control the temperature of the vessel. After fermentation, the beer may be left in the fermentation tank for conditioning and aging or drained from the fermentation tank and taken to the bright tank, where it conditions and ages. A small percentage of the yeast can be re-used, and the surplus yeast can be used as yeast tablets, animal feed or by distillers, although in some breweries it is simply washed down the drain (Briggs, et al., 2004; Olajire, 2012).

2.2.6 Bottling & Packaging

Once the beer has conditioned, yeast is filtered out and the beer is ready to be racked into kegs, casks, bottles or cans (Olajire, 2012; Bleier, et al., 2013; Banda, et al., 2015). Bottling and packaging activities include bottle soaking, washing and rinsing, labelling and packaging. Manual or automated bottling machines may be used. The bottles are washed, rinsed and labelled and then filled with the beer and packaged in boxes and sent to the cold-storage room. Kegs and casks are also filled and sent to the cold-storage room. The main focus areas for bottling and packaging to ensure quality include: prevention of oxygen from getting into the beer, maintenance of the correct temperature of beer in the bright tank and at filling stages, and maintenance of high levels of cleanliness with regards to the surroundings and equipment used in bottling and packaging (Briggs, et al., 2004):

Other elements that are of concern in the production of beer include (Briggs, et al., 2004):

- *Water management:* or example management of running hoses and leaks, provision of cleaning water, separate metering of water pumps to different vessels
- *Hygiene*: regular and thorough cleaning of the brewery, hard impermeable floors, which slope to a drain, as well as regular cleaning of all equipment used
- *Temperature control:* temperature must be managed and controlled at all processes that must adhere to specific temperatures.
- *Ventilation:* to avoid build-up of carbon dioxide
- *Lighting:* the brewery must be well lit

Craft brewing is very much like other production processes and uses a lot of resources such as energy and water (Boden, 2012). Current craft beer industry challenges include brewery acquisitions, difficulty in accessing quality ingredients, access to capital investments, access to distribution channels and customers, acquiring and developing craft breweries and strong competition from mega breweries that market their beer (Banda, et al., 2015). In order to become more competitive, craft breweries may need strategies to reduce production costs and increase efficiency. Lean production is an established strategy used by manufacturing companies to achieve these objectives.

2.3 Lean Production Framework

Craft brewers need to develop better ways to compete in this globally competitive beer industry. As a possible solution, production methodologies like lean production may be implemented to improve quality and efficiency, thereby reducing costs. According to Womack, Jones & Roos (1990), the term 'lean' was first used by John Krafick. He first used the term in 1987, to describe and explain a system that combined various aspects of management, including customer relationship management, product development, production, quality management and management philosophies that were initially established and developed by Toyota (Huxley, 2015).

This view is supported by other authors, who agree that lean production was derived from the Toyota Production System (TPS) (Stevenson, 2012; Schmidtke, Heiser, & Hinrichsen, 2014).

Lean production, sometimes referred to as lean management, is an integrated system, that aims at eliminating waste, by reducing variabilities or inconsistences that occur within internal processes, with suppliers and with customers (Mostafa, Dumrak, & Soltan, 2013; Saurin, Rooke, & Koskela, 2013). The main goals of a lean management system are to have materials and work flowing smoothly through the system, to remove disruptions and to minimise or remove wastes (Stevenson, 2012).

2.3.1 Lean Wastes

Lean production is a system that creates more value for customers by eliminating those activities that do not add value (Douglas, Jiju, & Douglas, 2015; Hampson, 1999). A distinction has to be made amongst the three types of activities in lean production. These are

1. Value adding activities (VA)
2. Necessary non-value adding activities (NNVA)
3. Non-value adding activities (NVA)

Value adding activities are those that the customers are willing to pay for because they are valuable. Necessary non-value adding activities refer to those activities that the customers may not find valuable but are necessary to the business, for example, inspection, and they occur due to the current business limits or because they are an activity that the business cannot do without. Non-value adding activities do not add value to the customer and are unnecessary and should, therefore, be eliminated (Hines & Taylor, 2000; Amid, 2013; Rich, Harrington, Voehl, & Wiggin, 2015).

The non-value adding activities are referred to as Muda in Japanese, which means waste (Belova & Yansong, 2008; Kilpatrick, 2003). The original seven wastes were identified by Taiichi Ohno, the founder of the Toyota Production System, in 1988 (Lacerda, Xambre, & Alvelos, 2016; Douglas, Jiju, & Douglas, 2015). Ohno (1988) identified the seven wastes as:

1. Waste of overproduction
2. Waste of time on hand (waiting)
3. Waste in transportation
4. Waste of processing itself

5. Waste of stock on hand (inventory)
6. Waste of movement
7. Waste of making default products

Stevenson (2012) notes these as *sources* of waste in production. He further adds that the wastes signify unproductive resources. The sources of waste include inventory, overproduction, waiting time, unnecessary transporting, processing waste, inefficient work methods and product defects. Another source of waste which has been recognized by the lean movement is described as a waste of underutilised human resources (Douglas, et al., 2015). This waste now constitutes the eighth waste in lean production. These are described below.

i. Inventory

This involves unnecessary raw stock on hand as well as large amounts of work-in-progress. Inventory as a source of waste is an indication that the system is not flowing smoothly. It is an idle resource and costs of holding inventory are also very high. This type of waste also creates long lead times. (Hines & Taylor, 2000; Belova & Yansong, 2008; Stevenson, 2012).

ii. Overproduction

Overproduction occurs when more is produced than that which the customer demands. Overproduction encompasses the unnecessary use of any production resource. It also leads to an increased storage time of the products as well as longer lead times and unnecessary work-in-progress (Hines & Rich, 1997; Austin, 2013; Stevenson, 2012).

iii. Waiting time

This source of waste requires space and occurs from products or an order queuing up to be processed. Waiting or idle time can also be a result of unbalanced workloads, unplanned or incorrectly planned production routines or overstaffing. (Agrahari, Dangle, & Chandratre, 2015; Stevenson, 2012).

iv. Unnecessary transporting

This involves the excessive movement of material, machinery, and manpower that are not required for a certain production process. This may be caused by a poor layout and disorganised workplaces (Hines & Taylor, 2000; Douglas, et al., 2015).

v. Processing waste

This source of waste is from unnecessary production processes. Scrap is an example of processing waste. Processing waste occurs when products are over processed, i.e. processed beyond what is required or the set standards. It can also occur when an incorrect product is continuously being processed (Hines & Taylor, 2000; Benson & Kulkarni, 2011; Stevenson, 2012).

vi. Inefficient work methods

Inefficient work methods are wasteful and they decrease productivity. Inefficient work methods involve the unnecessary movement of staff and machinery and may be caused by poor housekeeping, unclear material flow, untrained staff, or a poor production layout (Wang & Senzen, 2011; Machado & Leitner, 2010; Stevenson, 2012).

vii. Product defects

This waste involves any quality problems in production that will require a rework or cause the products to be scraped (Hines & Taylor, 2000; Wang & Senzen, 2011).

viii. Waste of underutilised human resources

This source of waste comes from not fully using the maximum capabilities of the employees in terms of their knowledge and skills (Stevenson, 2012; Douglas, et al., 2015).

2.3.2 Lean Benefits

The core objectives of lean production are to eliminate non-value adding activities – wastes - which have been discussed above. Eliminating waste creates production processes that drive down costs (Lacerda, et al., 2016; Schmidtke, Heiser, & Hinrichsen, 2014).

Many studies have been carried out in different industries implementing lean production methodologies and have reported successful outcomes from this approach (Anand & Kodali, 2009). For example:

Rajenthirakumar, Mohanram and Harikarthik, (2011) conducted a case study in the paint industry. They implemented a lean tool, value stream mapping (VSM) to reduce and eliminate waste from the production on the shop floor. The results indicated a reduction in cycle time and increased efficiency. In addition, some non-value adding activities such as bottlenecking time, materials handling time and waiting time were minimised.

In 2012, Jiménez, Tejeda, Pérez, Blanco and Martínez, conducted a multi-case study in the wine industry to improve the efficiency of the production process. VSM was used as the main tool for analysing the wastes. The researchers identified the tools which were applicable to the wine industry (for example, 5S, visual aids), partially applicable (for example, Kanban) and not applicable (for example, cellular manufacturing).

In 2013, researchers Rahman and Karim sought to identify and minimise waste so as to reduce operational and inventory costs. The research was carried out using a case study in the tile industry. A value stream mapping exercise was conducted to identify wastes. Other lean tools were used to identify the sources of wastes, namely the Ishikawa cause and effect diagram, to identify the root causes of the wastes.

Lacerda et al. (2016) implemented the VSM lean tool to identify and eliminate waste so as to increase quality and efficiency. They used a single case study and selected an equipment manufacturer for the automotive industry. The production process was studied and then this was followed by the VSM. The wastes were identified and the solutions were proposed. After application of these solutions, the results included reduced cycle time, a reduction in the number of operators that were needed, decreased inventory as well as an elimination of bottlenecks.

Survey research, with 51 apparel industry practitioners, was conducted by Raj, Yoon, Hae, and Banning (2017). Their research identified the level and use of lean production methodologies within the industry. The results showed that there was room for improvement in the industry and several suggestions were made to eliminate waste that occurred in the industry, for example, using minimum raw materials and reducing scrap.

Dhiravidamani, Ramkumar, Ponnambala and Subramanian (2017) implemented lean production practices that targeted the elimination of waste. They used a case study research design and conducted research in the auto parts industry. The tools used included VSM and Kaizen concepts. The results indicated a decrease in lead time, reduced setup times and a reduction in the rejection rate.

These are some examples of research that have been carried out with regards to the adoption and implementation of lean production methodologies across industries.

According to Melton (2005), Anand and Kodali (2009) as well as Singh, Garg, Sharma and Grewal (2010) some of the overall lean benefits include:

- Improved quality
- Reduced operational costs
- Increase in production output per person
- Fewer process wastes
- Decreased lead times
- Reduced work in progress
- Less rework
- Reduction in finished goods inventory

Some companies that have implemented lean methodologies have not attained these lean benefits because of a lack of understanding of the lean concept (Anand & Kodali, 2009; Miian, 2012). Lean critics, as cited by Samuel (2013), argue against the concept of lean production for various reasons.

They argue that lean is exploitative to the workers and increases stress levels for the workers (Hines, Holweg, & Rich, 2004; Samuel, 2013; Smits, 2012). Nayab (2011) argues that the workers are put under a lot of pressure to do better than before. He further argues that lean management makes the workplace too impersonal and scientific.

In addition, lean critics argue that the concepts of lean production are not transferrable to all sectors or industries as asserted by some researchers, for example, Deflorin and Scherrer-Rathje, (2012). Furthermore, they argue that lean management is not universally applicable and also raise questions about the financial benefits of lean management, disagreeing that there is enough evidence for the claims that lean management leads to financial benefits (Samuel, 2013; Smits, 2012).

Other arguments put forward against lean management are that lean production over-focuses on the elimination of waste and in some instances ignores other concerns, for example, employee wellness. Lean management's focus is on high productivity and efficiency, and sometimes the wellbeing of the employees are ignored. (Nayab, 2011). Some arguments against lean are based on the fact that lean production is too focused on the shop-floor alone (Hines, et al., 2004).

The absence of a standard implementation methodology in lean production is also a point of argument (Nayab, 2011). Since there are various lean tools and techniques that are used in the implementation of lean, for example, value stream mapping, Kaizen, etc., critics argue that people would be confused as to which tool or technique to utilise to best serve the company. However, it is important to note that the problems or drawbacks of lean production arise from the method of implementation rather than from a flaw in the lean culture.

Lean production was originally meant for big companies and then evolved to smaller production lines and service industries (Deflorin & Scherrer-Rathje, 2012). Schmidtke et al. (2014) argue that not all lean principles are universally appropriate or relevant across all sectors and industries. Therefore, it is essential to identify the lean principles, practices, tools and techniques that are applicable to the relevant industry and company before attempting to implement lean management.

2.4 Lean Elements

Anand and Kodali (2009) argue that the terminology used to describe lean elements - principles, practices, tool and techniques – is not standard as these terms are sometimes used interchangeably. It is important to define this terminology clearly.

Lean principles, for example, specifying value, are the basic rules that assist in managing the implementation of the lean process (Waleed & Chinweike, 2015). Lean practices are the methods used for the actual implementation of lean management, for example, Just-In-Time (JIT) (Stevenson, 2012; Waleed & Chinweike, 2015). A lean tool is an application that deals with a specified problem, for example, a control chart, whereas a technique is a practical method, which requires a set of skills to deal with a particular task or problem. For example, if you have variations in a process, the statistical process control technique may be used to tackle this problem (Antony, Escamilla, & Caine, 2003; Waleed & Chinweike, 2015).

The lean tools and techniques include; JIT, 5S, cellular manufacturing, poke-yoke, etc. The typical implementation decision is to choose which tools and techniques to apply to implement lean management (Pearce & Pons, 2013). The specific tools and techniques which are to be applied for specific industries or to specific situations have not been identified and this has been a cause of problems for businesses as well as areas of criticism against lean management (Samuel, 2013).

Lean practices are implemented using lean tools and techniques, for example, single-minute exchange of die (SMED), Kanban, etc. (Pearce & Pons, 2013). JIT (a practice) is implemented using tools and techniques that include, small lot sizes, single piece etc. (Jasti & Kodali, 2015). Table 2.1 provides definitions of some lean tools and techniques.

Table 2. 1 Lean Practices, Tools and Techniques

Tool/Practice/Technique	Definition
Andon	A manufacturing term referring to a signboard incorporating signal lights, audio alarms, and text or other displays installed at a workstation to notify management and other workers of a quality or process problem.
Bottleneck	A constraint, obstacle or planned control that limits throughput or the utilization of capacity.
Cause and Effect diagram	In quality management, a structured process used to organize ideas into logical groupings. Used in brainstorming and problem-solving exercises. Also known as Ishikawa or fish bone diagram.
Cell	An area of manufacturing or assembly which consists of a series of work units devoted to the manufacture of a specific product. Cellular manufacture is an alternative to the traditional production line.
Cellular manufacturing	A manufacturing approach in which equipment and workstations are arranged to facilitate small-lot, continuous-flow production. In a manufacturing "cell," all operations necessary to produce a component or subassembly are performed in close proximity, thus allowing for quick feedback between operators when quality problems and other issues

	arise. Workers in a manufacturing cell typically are cross-trained and, therefore, able to perform multiple tasks as needed.
Changeover	Process of making necessary adjustments to change or switchover the type of products produced on a manufacturing line. Changeovers usually lead to downtime and for the most part companies try to minimise changeover time to help reduce costs
Continuous Flow Manufacturing	A production system organized and sequenced according to the steps involved in the manufacturing process where the product moves seamlessly and continuously through the entire manufacturing process.
DMAIC	An acronym used by Six Sigma practitioners to remind them of the steps in a Six Sigma improvement project - Define, Measure, Analyse, Improve, Control
First In, First Out (FIFO):	Warehouse term meaning first items stored are the first used. In accounting this term is associated with the valuing of inventory such that the latest purchases are reflected in book inventory. While generally considered an accounting notion, FIFO usage is common where products may have a shelf life
Heijunka	An element of the Toyota Production System that averages volume and sequence of scheduled items to provide level production and help enable just in time (JIT).
Jidoka	The concept of adding an element of human judgment to automated equipment.
Just-in-Time (JIT)	An inventory control system that controls material flow into assembly and manufacturing plants by coordinating demand and supply to the point where desired materials arrive just in time for use. An inventory reduction strategy that feeds production lines with products delivered "just in time".
Kaizen	Taken from the Japanese words “kai” (change) and “zen” (good) literally “changes than make our product better”. The popular meaning has grown to include continual improvement of all areas of a company and not just quality. A business philosophy of continuous cost, quality problems, and delivery time reductions through rapid, team-based improvement activities.
Kanban	Japanese word for "visible record", loosely translated means card, billboard or sign. Popularized by Toyota Corporation, it uses standard containers or lot sizes to deliver needed parts to assembly line "just in time" for use. Empty containers are then returned to the source as a signal to resupply the associated parts in the specified quantity.
Lot Size	Set quantity of goods to be purchased or produced at one time in anticipation of use or sale in the future.

Milk run	Delivery method for mixed loads from different suppliers. Instead of each of several (say 5) suppliers sending a vehicle every week to meet the weekly needs of a customer, one vehicle visits each supplier on a daily basis and picks up deliveries for that customer
Muda	A Japanese term for waste, used in Lean management
Part Standardisation	A strategy designed to eliminate excessive SKU counts (part numbers) from inventory control systems through the use of common parts and components. Also knows as ‘rationalising’.
Plan-Do-Check-Action (PDCA)	A four-step quality improvement cycle, based on a process that involves continuous improvement based on analysis, design, execution and evaluation. Sometimes referred to as plan/do/study/act, it emphasizes the constant attention and reaction to factors that affect quality.
Poke Yoke (mistake - proof)	The application of simple techniques that prevent process quality failure. A mechanism that either prevents a mistake from being made or makes the mistake obvious at a glance.
Preventative Maintenance	Regularly scheduled maintenance activities performed in order to reduce or eliminate unscheduled equipment failures and downtime
Quality Circle	A group composed of individuals trained to identify, analyse and solve work-related problems.
Quality Control	The management function that attempts to ensure that the foods or services manufactured or purchased meet the product or service specifications
Six Sigma	Six-Sigma Quality: Six-Sigma is a term coined to stress the continuous reduction in process variation to achieve near-flawless quality. When a Six Sigma rate of improvement has been achieved, defects are limited to 3.4 per million opportunities.
Single Minute Exchange of Die (SMED)	A manufacturing procedure which provides for a rapid and efficient way of converting a manufacturing process from running the current product to running the next product.
Statistical Process Control (SPC)	A method for achieving quality control in processes. The technique hinges on the observation that any process is subject to seemingly random variations, which are said to have common causes and non-random variations, which are said to have special causes.
Takt Time	It can be defined as the maximum time per unit to produce a product in order to meet demand. It is derived from the German word “Taktzeit” (cycle time). Takt time sets the pace for industrial manufacturing lines. For example, in automobile manufacturing, cars

	are assembled on a line and are moved on to the next station after a certain time—the takt time.
Total Productive Maintenance	Team based maintenance process designed to maximize machine availability and performance and product quality.
Total Quality Management	A management approach in which managers constantly communicate with organisational stakeholders to emphasize the importance of continuous quality improvement.
Value Analysis	A method to determine how features of a product or service relate to cost, functionality, appeal and utility to a customer (i.e., engineering value analysis).
Value Chain Analysis	A method to identify all the elements in the linkage of activities a firm relies on to secure the necessary materials and services, starting from their point of origin, to manufacture, and to distribute their products and services to an end user.
Value Stream Mapping	A pencil and paper tool used in two stages: 1. Follow a product's production path from beginning to end and draw a visual representation of every process in the material and information flows. 2. Then draw a future state map of how value should flow. The most important map is the future state map.
5S	A program for organizing work areas. Sometimes referred to as elements, each of the five components of the program begins with the letter "S." They include sort, systemize, shine or sweep, standardize and sustain.

Source: *(Adapted from Vitasek, 2013)*

The lean principles which are necessary to eliminate waste were originally identified by Womack and Jones (1996) and include:

- Specifying value
- Identifying the value stream
- Making value flow
- Pull scheduling
- Seek perfection

(Womack & Jones, 1996; Moore & Scheinkopf, 1998; Belova & Yansong, 2008,). These are discussed below.

i. Specifying Value

Value is defined by the customer. It is what the consumers are willing to pay for a product or service. Specifying value involves identifying what does and what does not create value, from the customer's view point (Womack & Jones, 2003; Hines & Taylor, 2000: Ugochukwu, et al., 2012).

ii. Identifying the value stream

All the steps and processes that are required for designing, ordering and producing the product are identified in a value stream. The value stream will identify the value adding, necessary non-value adding as well as non-value adding activities. The goal in this step is to eliminate most of the non-value adding activities (Belova & Yansong, 2008; Womack & Jones, 2003; Ugochukwu, et al., 2012).

iii. Making value flow

The third principle is creating an efficient system by making the activities that create value flow without any interruptions or waiting periods (Hines & Taylor, 2000; Ugochukwu, et al., 2012).

iv. Pull scheduling

The fourth principle focuses on making only what is required - pulled - by the customer. In this case, overproduction is avoided and also waste from inventory is eliminated (Womack & Jones, 2003; Hines & Taylor, 2000; Ugochukwu, et al., 2012).

v. Seek perfection

The fifth lean principle, perfection, has a continuous improvement outlook that looks beyond the current situation and puts mechanisms in place to continually eliminate waste as it occurs (Hines & Taylor, 2000; Ugochukwu, et al., 2012).

Based on the original lean principles provided by Womack and Jones, researchers have subsequently developed and further categorised these lean principles. For example, in 1996, researchers Karlsson and Åhlström (1996) documented nine lean principles: elimination of waste, continuous improvement, zero defects, Just-in-Time, pull instead of push, multifunctional teams, decentralized responsibilities, integrated functions, and vertical information systems. However, this categorisation was criticised by Anand and Kodali (2009) who argued that integrated functions, multifunctional teams, decentralised responsibilities and vertical information systems were not necessarily lean principles.

The model of Karlsson and Åhlström was modified by Sánchez and Pérez (2001). These researchers provided a categorisation of the lean principles. These categories include the elimination of zero-value activities, continuous improvement, multifunctional teams, JIT production and delivery, integration of suppliers and flexible information systems (Sánchez & Pérez, 2001).

Recently, Jasti and Kodali (2015) provided a lean typology that builds on the original work of Womack and Jones (1996) and Anand and Kodali (2009). This framework proposes eight categories of lean principles (continuous improvement, logistics management, customer relationship management, JIT production, elimination of waste, supplier management, top management commitment and information technology management) and gives a clear list of the tools that can be used under each category (Jasti & Kodali, 2015). Table 2.2 shows the principles in bold, as well as the lean tools and technique under each principle that are implemented when adopting lean production.

Table 2. 2 Lean Principles, Tools, and Practices

Information Technology Management
Use of EDI to communicate between departments, Centralised database for documentation, Enterprise resource planning system, Information technology employed at customer base, Effective and transparency information flow throughout supply chain, use of bar coding and scanner in logistics systems, Electronic commerce, Modelling analysis and simulation tools, Computer-aided decision-making supporting systems
Supplier Management
Strategic supplier development, Supplier evaluation and certification, Long-term supplier partnership, Supplier involvement in design, Supplier feedback, Supplier proximity, Single source and reliable suppliers or few suppliers, Cost-based negotiation with suppliers, Manage suppliers with commodity teams, Joint decisions towards cost savings
Elimination of Waste
Standard products and processes, Standard containers, Focused factory production, Design for manufacturing, Flexible manufacturing cells or U-shape manufacturing cells, Visual control, Single minute exchange of die, Andon, 5S, Point of use tool system, seven wastes throughout supply chain

JIT Production
JIT deliveries throughout supply chain, Single piece flow, Pull production, Kanban, Production levelling and scheduling, Synchronised operational flow, Plant layout, Point of usage storage system, Pacemaker, Small lot size
Customer Relationship Management
Specification of value in terms customer point view, post sales service to customer, Customer involvement in design, Continuous evaluation of customers feedback, Customer enrichment, Concurrent engineering, Group Technology. Delivery performance improvement, Takt time, Quality function deployment, Failure mode and effect analysis
Logistics Management
Time windows delivery requirements or tight time windows, Effective logistics network design, Consultants as logistics managers, Consignment inventory or vendor managed inventory, Advance material requirement planning and scheduling structure, Use of third party logistics for transportation system, Milk run or circuit delivery, Master the demand forecasting process, postponement, ABC material handling, Elimination of buffer stocks
Top Management Commitment
Create vision and objective to lean supply chain, Employee training and education in LSCM, Organisation structure and associated relationships, Cross-enterprise collaborative relationships and trust, Joint planning of processes and products with suppliers, Resources allocation, Develop learning culture specific organisation, Holistic strategy for integrating system or organisational policy deployment, Employee empowerment, Stable and long-term employment, Leadership development
Continuous Improvement
Multi-skilled workforce, Built in quality system, Value stream mapping through supply chain, New product development, Statistical process control, Quality improvement teams or quality circles, Cross functional teams within the organisation, Use of flat hierarchy, Value engineering

Source: *(Jasti & Kodali, 2015)*

This study was particularly concerned with how these production tools and techniques might be applied in smaller enterprises than those for which they were originally developed. This is discussed in the next section.

2.5 Lean Production for Small and Medium Enterprises

Studies indicate that the use of lean production systems has led to improved performance for organisations, for example, Rolls Royce, Airbus and Weston Aerospace (Anand & Kodali, 2009; Saskia, 2014). Notably, most of the research on lean and the frameworks developed are for large organisations, such as the one provided by Jasti and Kodali (2015), and not for small or medium enterprises.

Small and medium enterprises (SMEs) are organisations that have between 20 and 50 employees for a small enterprise and 51 to 200 employees for an enterprise considered medium. A further classification is of enterprises with less than 20 employees, known as micro or very small enterprises. Countries and regions around the world use varying definitions and classifications of SMEs (Wiese, 2013). Table 2.3 provides the broader definitions of SMEs used in South Africa. This research will use the broader classification of SMEs, as shown in table 2.3.

Table 2. 3 Definition of SMEs in South Africa

Enterprise size	Number of employees	Annual turnover	Gross assets (excluding fixed property)
Small	Fewer than 50	Less than R2m to R25m depending on the industry	Less than R2m to R4.5m depending on the industry
Medium	Fewer than 100 to 200, depending on the industry	Less than R4 million to R50 m depending upon the industry	Less than R2 m to R18 m depending on the industry

Source: *(Wiese, 2013)*

For SMEs, the major challenge with regards to lean implementation is to know which practices, as well as tools and techniques to implement and how these can be applied to improve efficiency (Pearce & Pons, 2013; Belhadi, Touriki, & Fezazi, 2016).

When implementing lean production, SMEs should do this step by step, using lean practices, tools and techniques which are in their control and which can be managed by the limited resources typical of small businesses (Rose, Deros, & Rahman, 2010).

SMEs, with particular reference to those in the small food and drinks manufacturing, for example, maize crisps production, craft brewing, etc., are also faced with challenges of identifying which set of lean tools and techniques to select and implement (Lopes, Freitas, & Sousa, 2015).

Table 2.4 shows a summary of the lean practices, tools and techniques that are suggested for SMEs by various researchers and have been used to implement lean production methodologies (Rose, Deros, Rahman & Nordin, 2011; Matt & Rauch, 2013; Belhadi, Touriki, & Fezazi, 2016). These authors were chosen because their conclusions are based on studies that have been carried out in

SMEs in various industries. Also, there are consistencies in the lean production tools and techniques suggested by the three sets of authors that can be used by SMEs.

Table 2. 4 Lean practices, tools, and techniques for SMEs

	Rose et al., (2011)	**Matt & Rauch (2013)**	**Belhadi et al., (2016)**
Lean Tools and Techniques	Set up reduction	Set up reduction	Statistical Process Control
	Visual control	Visual management	Pareto Analysis
	Cell layout	Cellular manufacturing	U-Cell
	5S	5S	5S
	Small lot sizes	JIT deliveries	Six Sigma
	Kanban	Benchmarking	Kanban
	Continuous flow	Pull principle	TOC
	Continuous Improvement	Kaizen – continuous improvement	Kaizen
	Uniform workload	Value stream mapping	Value stream mapping
		First In First Out	First In First Out
	TQM / TQC	Zero defects	Cost Deployment
	Standard operation	Poke yoke and standardisation	Work standard and knowledge management
Lean Practices	Preventive maintenance	Low cost automation	TPM
	Teamwork	Idea management to utilise the worker's know how	Master plan
	Quality circles	Job rotation	Scoreboard
	Multifunctional employees	Efficient & ergonomic workstations	Multifunctional team
	Training		Training
	Supplier management		

Source: (*Compiled by the researcher)*

2.6 Lean Implementation within Organisations

Belhadi et al. (2016) developed a framework for the implementation of lean production within organisations (Figure 2.3). This has been used to group lean tools and techniques according to the stage at which they are introduced into an organisation. The four stages identified by these authors are: mapping the process, organising the house, improving the process and sustaining the results.

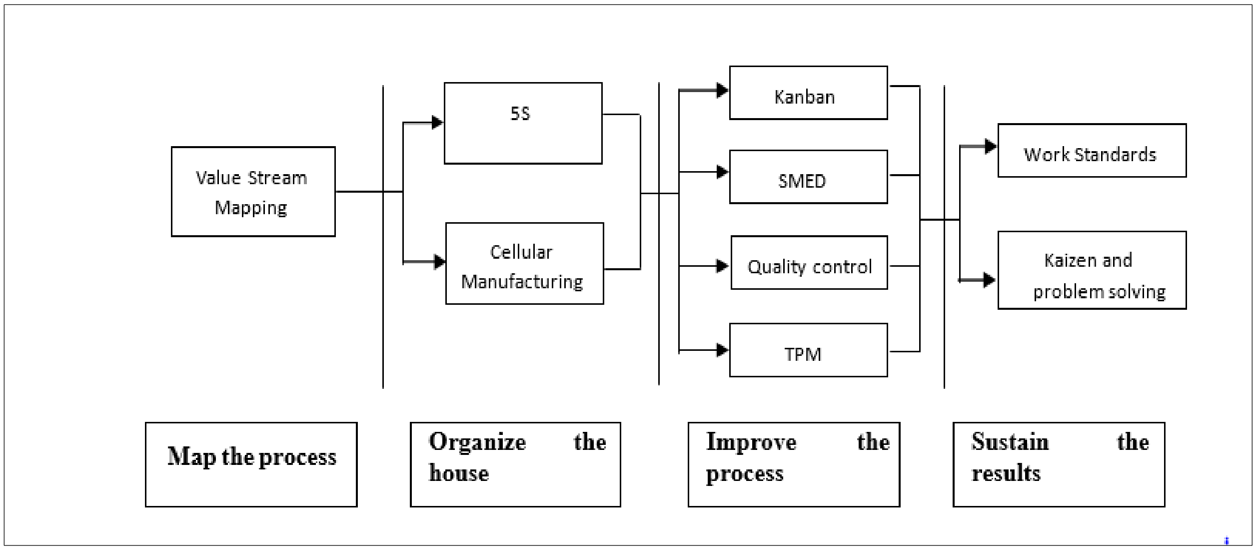


Figure 2. 3 Lean Conceptual Framework

Source: *(Belhadi, Touriki, & Fezazi, 2016)*

2.6.1 Mapping the process

Mapping the process entails studying the transformation process from start to finish using lean tools like Value Stream Mapping (VSM) (Belhadi, et al., 2016). VSM is a tool that is used to map out or show the production activities that are involved in making a product. It also identifies the wastes, i.e. identifies the processes or activities that do not add value to the final product and inefficiencies that are in the current process (Braglia, Carmignani & Zammori, 2006; Rother & Shook, 2009). This VSM tool has been used and tested in various industries using the case study approach. These include the tile industry (Muzunzi, Maware, Chinguwa & Mwodza, 2013), health-care (Machado & Leitner, 2010) and the camshaft manufacturing industry (Vinodh, Arvind, & Somanaathan, 2010), amongst others.

There are different value streams used by various researchers and practitioners (Hines & Rich, 1997). Jones (2013) emphasizes that value stream mapping is not always created or determined the same way and he describes the starting points or focus areas for each industry. These focus points influence the methodologies used for conducting value stream mapping exercises.

Table 2. 5 VSM Industry and Focus Area

Industry	**Starting point/ Focus Area**
Automation and Assembly	Creating standard work Improving process capabilities Creating continuous flow
Process Industry	Patterned production Reduced batch sizes Elimination of inventories
Retail and Distribution	Uncovering hidden costs in inventory
Services and Repair	Turning unpredictable work to predictable work
Healthcare	Making patients visible Synchronise support services with demand
Financial services	eliminate the root causes of unnecessary demand created by the broken process

Source: (*Jones, 2013)*

Specific industries with varying focus areas as presented in the table above can decide on which value stream mapping tool they want to use. Value stream mapping has several tools or methodologies that are used (Hines & Rich, 1997; Pude, Naik & Naik, 2012) and these include:

1. Process activity mapping
2. Supply chain response matrix
3. Production variety funnel
4. Quality filter mapping
5. Demand amplification mapping
6. Decision point analysis
7. Physical structure mapping

This research will employ the first tool, process activity mapping because it maps out in detail the current process and identifies waste in order to improve the process. In addition, this methodology was chosen because it allows for the study of the flow of processes that are involved in the production process. Also, the process activity mapping allows for the easy identification of non-value adding activities, i.e. wastes as well as inefficiencies. Furthermore, it considers if the processes can be rearranged in more efficient sequences. Finally, it considers whether a better flow pattern and layout can used to arrange the machinery and what would happen if some tasks and processes were to be removed (Pude, Naik & Naik, 2012).

This research is similar to that of Rajenthirakumar et al. (2011) who applied lean methodologies in a paint shop. In their research, they used the value stream mapping technique to identify wastes and to improve productivity and efficiency. As a result of using VSM, cycle times were reduced and lead times were shortened. The researchers also used a single case study design as their research strategy (Rajenthirakumar, et al., 2011).

This first step in this framework requires that a current state analysis of the production process be conducted, using a value stream mapping exercise. The following diagram shows how to conduct a current state analysis.

Identify & Select Product Family

Bound the process and identify the process steps

Gather material & Information flow

Collect Process Data

Draw current state map

Identify Wastes

Figure 2. 4 Current State Analysis Process Steps

Source: (*Rother & Shook, 2009; Salunke & Hebbar, 2015)*

i. Identify & Select Product Family

A product family is a set of the products that pass through closely related process steps and use similar equipment during production (Rother & Shook, 2009; Locher, 2008; Salunke & Hebbar, 2015). Some companies make more than one product and thus it is essential to determine which product family is being mapped. If a company has more than one product a matrix like the one shown in Table 2.6 is used to identify the product family.

Table 2. 6 Product Family Matrix

Process Steps						
Product	***1***	***2***	***3***	***4***	***5***	***6,7,8…***
A	X		X	X	X	
B		X	X		X	
C	X		X	X	X	
D		X			X	
E, F, G…						

Source: *(Dolcamascolo, 2006)*

Table 2.6 lists the process steps in rows, with the products listed in columns. The next step is then to mark for each product the process steps that the products pass through. From the matrix, we can determine that products A and C are closely related as they pass through similar steps and thus are in the same product family (Dolcamascolo, 2006; Salunke & Hebbar, 2015).

ii. Bound the process and map the process steps

The next step is to set the boundaries for the process, i.e. to determine the starting point and the end point. Boundaries are set to assist in deciding the limits of the map so as to provide specific focus points (Earley, 2013). For example, value streams can be mapped from the supplier to the customer, or from the factory to the customer. When the boundaries have been set, the major process steps involved are identified (Rother & Shook, 2009), for example, in craft brewing a process step would be mashing.

iii. Describe material & information flows

Material flow shows the movement of raw materials throughout the transformation until the finished product reaches the customer. For example, in brewing, it would show how raw materials flow from the mashing stage right through the final stage.

The information flows indicate how information is passed from one user to the next and what type of information is passed (King & King, 2015). Information flows also show how products are ordered by the customer, the method and frequency with which this happens as well as information flows that communicate the requirements for each process (Earley, 2013).

iv. Collect process data

The major processes are recorded along with the process information in a process box. The information that is collected is listed in Table 2.7. Process information is data that is collected regarding each step of the process. This information is recorded in a box, i.e. process box.

Table 2. 7 Process Steps Data

Cycle time	Time that is taken to make one product
Changeover time	From last good piece to next
Uptime	The amount of time the process is producing the product
Number of operators	Number of workers assigned to a process
Pack size	Amount of product grouped as one unit of production
Batch size	Total number of packs in one production unit
Net available working time	Total amount of time available excluding break times
Scrap rate	Percentage of product at a process that does not meet quality standards

Source: (King, 2004; Rother & Shook, 2009; Earley, 2013)

v. Draw current state map

This step can be conducted simultaneously with the steps above or once all data has been collected. When mapping the current process, a set of lean symbols are used to do this. Figure 2.5 shows the typical lean tools used for mapping.

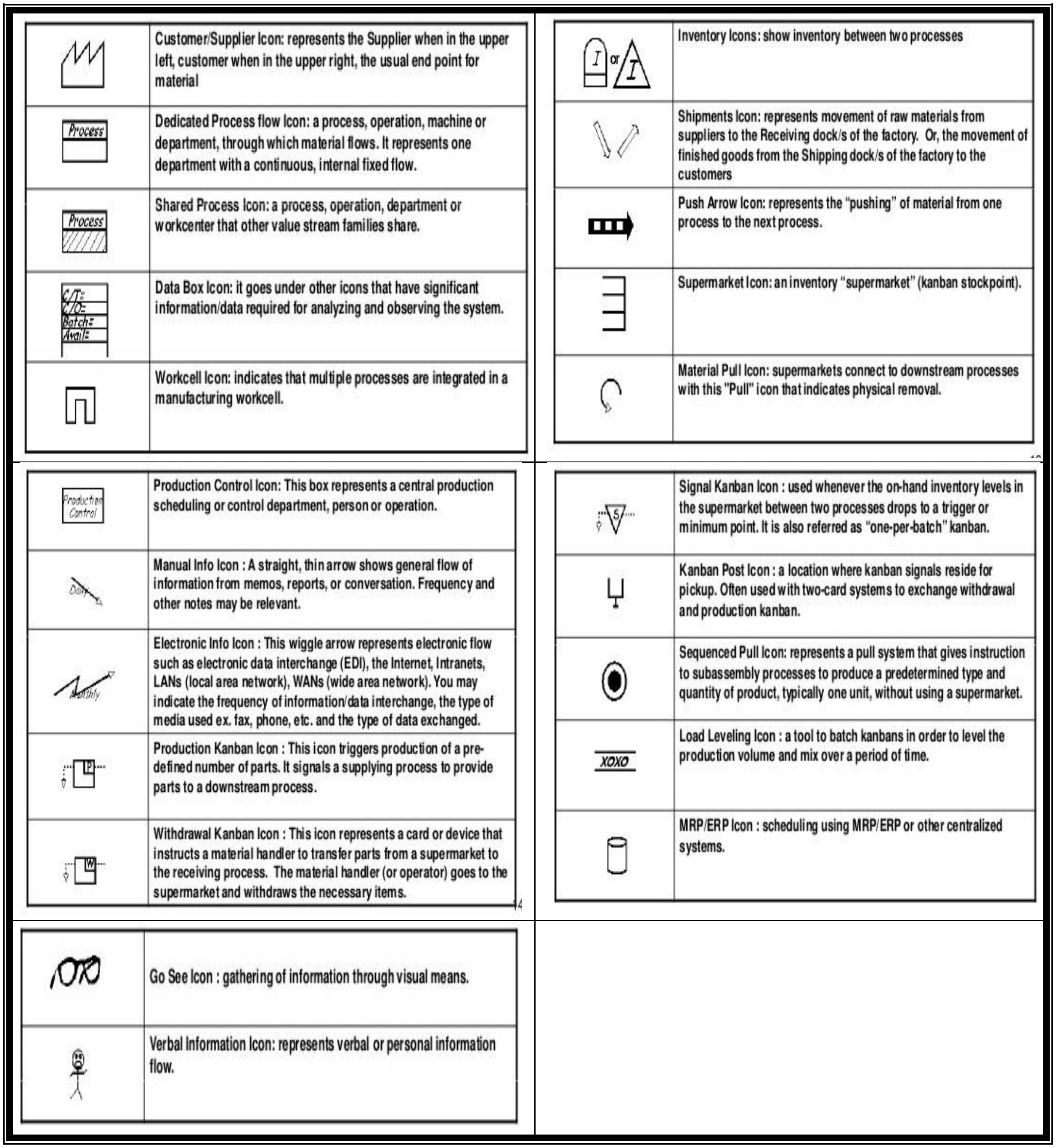


Figure 2. 5 Lean Symbols

Source*: (Rother & Shook, 2009)*

A sample current state map is illustrated in Figure 2.6. When drawing the 'current state' map, the symbols provided in Figure 2.5 are typically used and the map may resemble the one shown in Figure 2.6 (Earley, 2013; Odessa Corp, 2017).

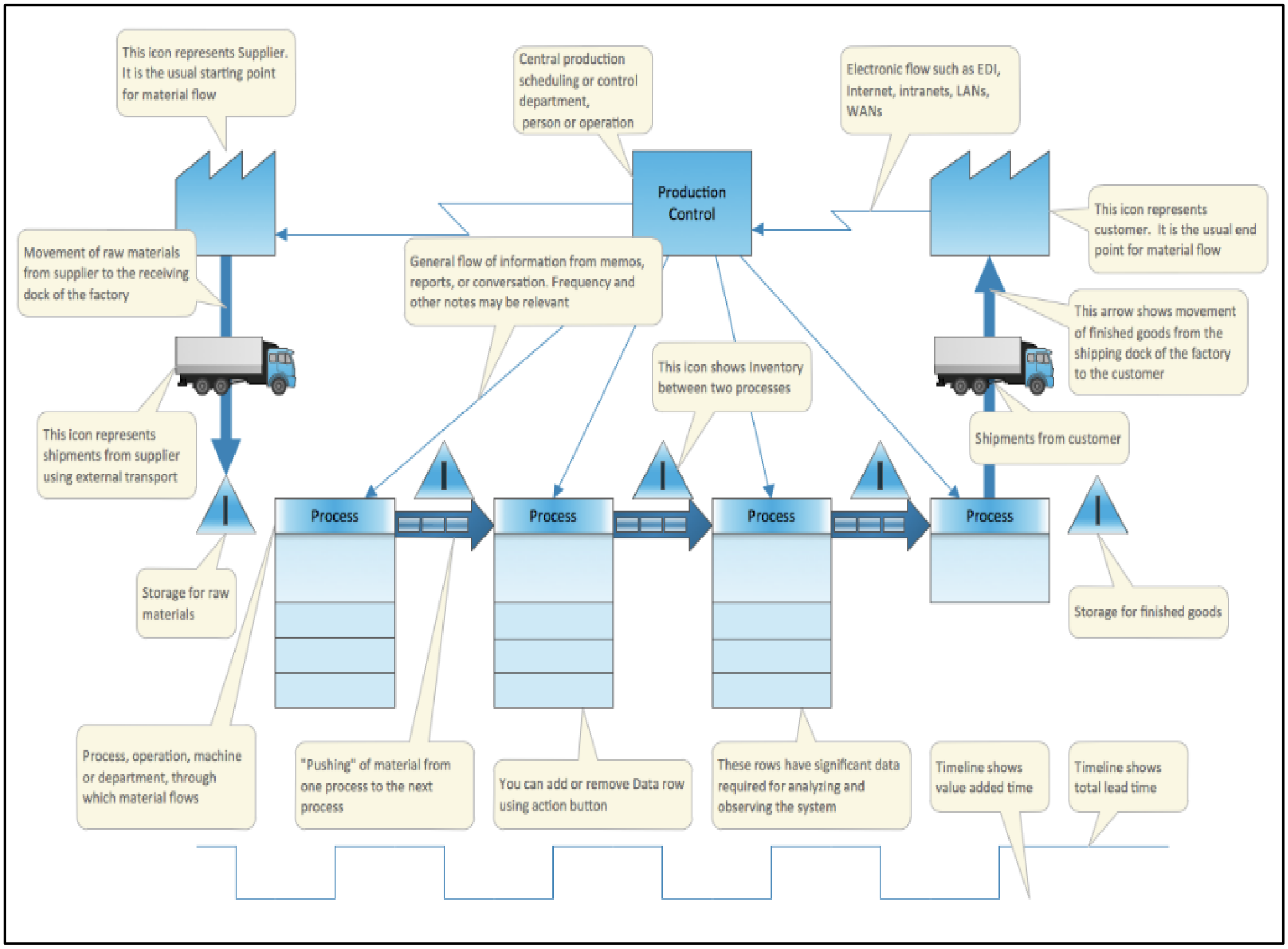


Figure 2.6 Current State Map

Source: *(Odessa Corp, 2017)*

vi. Identify waste

The last part of this step is to identify the lean wastes and where they occur in the production process. The sources of lean wastes which were discussed earlier in the chapter include inventory, overproduction, waiting time, unnecessary transporting, processing waste, inefficient work methods, product defects and underutilized human resources. (Hines & Taylor, 2000; Stevenson, 2012). These wastes or inefficiencies are identified from within the processes. Once this is done, areas that are best suited for smoothing the flow are also determined.

2.6.2 Organise the house

After mapping the 'current state', the second stage in the framework is to organise the production facility by introducing the fundamental lean tools (5S and cellular manufacturing) on which the other lean elements can then be built (Belhadi, et al., 2016). Cellular manufacturing allows for the arrangements of workstations and equipment in a way that promotes a smooth flow of the materials throughout the production process (Wang & Senzen, 2011).

The 5S, also known as housekeeping philosophy, consists of five activities as depicted in Figure 2.7 . These are sort, set in order, shine, standardise and sustain. Together, these activities are used as a clean-up tool which is used, in conjunction with VSM, towards a lean organisation (Moore & Scheinkopf, 1998; Belhadi, et al., 2016).

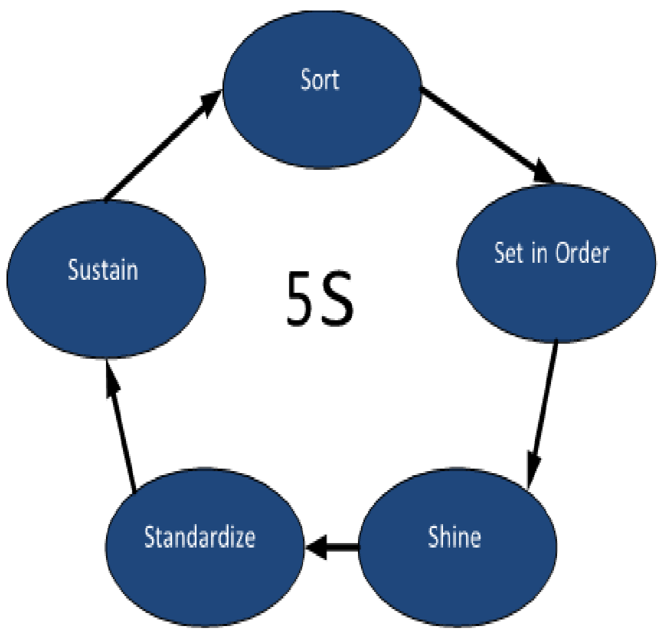


Figure 2. 7 5S/ housekeeping

Source: *(Tapping & Shuker, 2003)*

i. Sort

Sorting involves going through an area in the organisation, removing all unnecessary items such as files, books as well as broken items and items that have reached their lifetime (Tapping & Shuker, 2003). Austin (2013) adds that in removing unnecessary items, the decision on removing an item must be based on when it was last used, for example, if it was not used in the last 14 days it should go to the main storage area.

ii. Set in Order

All items that are necessary should be placed neatly and in an orderly manner. Items should be labelled so that they are easily accessible. In production areas, colour coding can be used for easy access (Srinivansan, 2012; Tapping & Shuker, 2003).

iii. Shine

The shining activity involves cleaning the work area as well as cleaning all the machinery. Daily schedules should be put in place for these activities (Tapping & Shuker, 2003; Srinivansan, 2012)

iv. Standardise

Standardising emphasises the best practices by creating standard operating procedures (Tapping & Shuker, 2003; Srinivansan, 2012). The purpose of this step is to standardise what has been done within the first three steps of 5S. This ensures that the most efficient ways of conducting tasks are performed in a repeatable manner through documented instructions or standard operating procedures (Earley, 2013).

v. Sustain

This involves creating ways of maintaining these changes in the organisation and communicating these within the organisation, to ensure that everyone understands and follows these changes (Tapping & Shuker, 2003; Srinivansan, 2012).

Once the processes have been mapped so that the wastes and inefficiencies have been identified and systems put in place in the areas that require reorganisation, the next stage will be to introduce improvements to existing processes. This is discussed in the next section.

2.6.3 Improve the Process

The third stage in the framework is to make improvements to the process. Here, the lean tools and techniques that are suggested in this framework may be implemented. For SMEs, these tools - which have been already discussed - would include Kanban system, quality control, total productive maintenance (TPM) and single minute exchange of die (SMED) (Belhadi, et al., 2016). For example, quality control measures, like the poke yoke technique, could be put in place so as to ensure that what is being produced is to product/service specifications Additional lean tools and techniques suggested for SMEs as discussed earlier may also be used to improve the process.

2.6.4 Sustain the Results

To maintain the results, standard operating procedures are further developed to achieve uniformity of the production process. These guidelines should incorporate the changes that would have been made from the previous stages.

Continuous improvements are made to the process, not as a once-off exercise but as an on-going one. Changes are made where necessary and this leads to an efficient production process as well as improved quality (Wang & Senzen, 2011).

2.7 Extension of the Lean Concept to Supply Chains of SMEs

Most of the lean implementation models as described in the literature in previous sections, have been internally focused on the operations. Organisations have realised that in order to be lean, the focus must also be extended to the entire supply chain network (Beamon, 1998; Ugochukwu, Engstrom, & Langstrand, 2012). The supply chain network is a system of all the activities and functions involved in the development of a product - procuring the materials, manufacturing the product and distribution of the products to the end-user (Chin, Hamid, Rasli, & Baharun, 2012). It is a network of organisations involved through upstream and downstream activities, in various processes and activities that produce value in the form services or products for the final customer (du Toit & Vlok, 2014).

The conceptual framework, shown in Figure 2.3, is internally focused, as it looks at lean from the internal operation activities. However, operational activities are influenced by other forces, for example, the suppliers, consumers, economic forces, governmental forces, technology as well as socio-cultural pressures (Chin, et al., 2012). Rymaszewska (2014) adds that lean management is a holistic view and looks at the activities of the entire value stream: the suppliers, internal activities, and customers.

SMEs implement supply chain management differently from large organisations. According to Arend and Winser (2004), as cited by Thakkar, Kanda, & Deshmukh (2008), the differences in implementation between large organisations and SMEs are that SMEs do not focus on proximity with partners and extending their chains. Also, SMEs are not concerned with improving the chain’s performance or relationships and do not implement SCM as deeply as large enterprises. However, it is important that, when adopting lean operations, relationships cross company boundaries and relationships are set up with customers and suppliers thus setting up supply chain networks for SMEs (Panizzolo, Garengo, Sharma & Gore, 2012).

Panizzolo et al. (2012) suggested an assessment tool, shown in Table 2.8, which can be used by SMEs seeking to implement lean operations to allow them to describe and measure, in order to operationalise, the lean production concept in the various areas of the firm.

Table 2. 8 Lean assessment tool

AREAS OF INTERVENTION		**IMPROVEMENT PROGRAMMES**
Process & Equipment	PE1	Set up reduction
	PE2	Flow lines
	PE3	Cellular manufacturing
	PE4	Rigorous preventive maintenance
	PE5	'Error proof' equipment
	PE6	Progressive use of new process technologies
	PE7	Process capability
	PE8	Order and cleanliness in the plant
	PE9	Continuous reduction of cycle time
Manufacturing Planning & Control	PPC1	Levelled production
	PPC2	Synchronised scheduling
	PPC3	Mixed model scheduling
	PPC4	Under-capacity scheduling
	PPC5	Small lot sizing
	PPC6	Visual control of the shop floor
	PPC7	Overlapped production
	PPC8	Pull flow control
Human Resources	HR1	Multifunctional workers

	HR2	Expansion of autonomy and responsibility
	HR3	Few levels of management
	HR4	Worker involvement in continuous quality improvement programmes
	HR5	Work time flexibility
	HR6	Team decision making
	HR7	Worker training
	HR8	Innovative performance appraisal and performance related pay systems
Product Design	PD1	Parts standardisation
	PD2	Product modularisation
	PD3	Mushroom concept
	PD4	Design for manufacturability
	PD5	Phase overlapping
	PD6	Multifunctional design teams
Supplier Relationships	SR1	JIT deliveries
	SR2	Open orders
	SR3	Quality at the source
	SR4	Early information exchange on production plans
	SR5	Supplier involvement in quality improvement programmes
	SR6	Reduction of number of sources and distances
	SR7	Long-term contracts
	SR8	Total cost supplier evaluation
	SR9	Supplier involvement in product design and development
Customer Relationships	CR1	Reliable and prompt deliveries
	CR2	Commercial actions to stabilize demand
	CR3	Capability and competence of sales network
	CR4	Early information on customer needs

	CR5	Flexibility on meeting customer requirements
	CR6	Service-enhanced product
	CR7	Customer involvement in product design
	CR8	Customer involvement in quality programmes

Source: *(Panizzolo et al., 2012)*

This tool was chosen because it includes a network focused approach, as it includes supplier and customer focus areas. Furthermore, it offers specific guidelines which can be used for the assessment of the current state of an enterprise and to guide its programme of continuous improvement,

The lean tool consists of a variety of best practices from different areas of the company, which must be implemented by an organisation that aims to become lean. These areas include; supplier relationships, process and equipment, manufacturing planning and control, human resources, product design and customer relationships (Panizzolo, et al., 2012). These are discussed in the following section.

2.8 Lean Assessment Tool: Operationalisation

The following section discusses the areas of intervention as provided by Panizzolo et al. (2012), and the suggested improvement programmes available for each area when implementing lean methodologies which are referred to by other researchers as lean tools. These areas of intervention are implemented using various lean practices, tools, and techniques.

2.8.1 Process & Equipment

Process selection involves deciding on the way the production of the goods will be organised. The process selected has key implications for the layout of the facility, capacity planning, the equipment chosen as well as the work methods (Stevenson, 2012). Lean improvement programmes for this decision area include: set up reduction, flow lines, cellular manufacturing, rigorous preventive maintenance, error-proof equipment, progressive use of new process technologies, process capability (i.e. the ability of the process to yield output within the process specification limits) order and cleanliness in the plant and continuous reduction of cycle time (Panizzolo, et al., 2012). Introducing these programmes has several benefits including reduced lead times, reduced inventory and better and faster equipment amongst others (Alves, Cavalho, Sousa, Moreira & Lima, 2011).

2.8.2 Manufacturing Planning & Control

Manufacturing planning and control objectives include the synchronization of market and production demand, speeding up the flows and making management simple. The improvement programmes include: levelled production, synchronised scheduling, mixed model scheduling, under-capacity scheduling, small lot sizing, visual control of the shop floor, overlapped production, and pull flow control (make-to-order) (Panizzolo, et al., 2012). For example, production levelling reduces the unevenness in production and also minimises waste, reduces the load on the employees and avoids overloading the machinery (Bohnen & Deuse, 2011), whilst mixed model scheduling allows for a number of products to be produced on a single assembly line (McMullen & Tarasewich, 2005).

Small lot sizing and visual controls are beneficial in that these reduce in-process inventory and as a result, reduce costs associated with handling and keeping inventory. Small lot sizes allow for flexibility in scheduling production (Stevenson, 2012) and also reduce variability in production (Yuan, 2010). Visual controls aim to make processes more effective and efficient by making the processes and information more visible to the workers at the right time and place throughout the factory (Wang & Senzen, 2011; Ortiz & Park, 2011).

2.8.3 Human Resources

Human resources are of great importance because they are part of the building block of lean production. Workers are seen as assets and are cross-trained and given responsibility for the implementation and improvement of production processes (Stevenson, 2012). Continuous quality improvements that are implemented are only possible through a good and dedicated workforce. The improvement programmes that are available for this area include: multifunctional workers, expansion of autonomy and responsibility, few levels of management, worker involvement in continuous quality improvement programmes, work time flexibility, team decision making, worker training, innovative performance appraisal and performance related pay systems (Panizzolo, et al., 2012; Martínez-Jurado, Moyano-Fuentes & Jerez-Gómez, 2014).

2.8.4 Product Design

According to Stevenson (2012), there are four elements with regards to product design that are important for a lean production system. These are standard parts, modular design, concurrent engineering as well as highly capable production systems (Stevenson, 2012). Concurrent engineering is a team approach whereby the product and the manufacturing or production processes are designed at the same time, as opposed to sequentially. The ease and cost of manufacturing, quality problems as well as customer needs are considered earlier in the development stages (Vitasek, 2013). On the other hand, modular design allows for the subdivion of a product into smaller parts called modules that can be easily used interchangeably (Stevenson, 2012; Vitasek, 2013). The improvement programmes for this area include parts standardisation, product modularisation, mushroom concept, design for manufacturability, phase overlapping and multifunctional design teams (Panizzolo, et al., 2012). Standardisation of parts, i.e. products, processes, containers, involves eliminating a number of variations of the products or processes and leads to an increased interchangeability of products as well as greater flexibility (Wild, 2003).

Standard containers are an element of the Kanban control system. Standard containers are used in production so as to make the processes similar and reduce costs (Garcia-Alacaraz & Maldonado-Marcia, 2014). The mushroom concept, a concept that allows for the products as well as parts and processes to be standardised and only differentiated at the end stage of production (Mere, 1990; Khusaini, Jaffar & Yusoff, 2014). Design for manufacturability (DFM) is designing for ease of manufacturing of the assortment of parts that will form the product after assembly (Poli, 2001; Madrid, 2012). This means that products are actively designed to optimise all the manufacturing functions and also assure the best cost, quality, reliability, regulatory compliance, safety, time-to-market, and customer satisfaction (Stevenson, 2012).

2.8.5 Supplier Relationships

Supplier relationships focus on the external networks of the firm (Panizzolo, et al., 2012; Rymaszewska, 2014). The improvement programmes for this area include JIT deliveries, open orders, and quality at the source. Ensuring quality standards are maintained will ensure that the end product is of good quality. Just-In-Time (JIT) production system involves the management of supplying the right product at the right time, right quantity, right quality and the right place (Kootanaee, Babu & Talari, 2013). It is a repetitive manufacturing production system in which processing and movement of material and goods occurs just as they are needed (Stevenson, 2012). For JIT to be successfully implemented throughout the supply chain, all companies must have a JIT oriented strategy. They must be effective with regards to quality, cost, flexibility, reliability and delivery speed (Olhager, 2002). Kannana & Tan (2005) added that in order to implement JIT deliveries effectively, a collaboration of schedules with the supply chain members is a necessity. Additional improvement programmes include; early information exchange on production plans, supplier involvement in quality improvement programmes, reduction of number of sources and distances, long-term contracts, total cost supplier evaluation and supplier involvement in product design and development (Panizzolo, et al., 2012). Exchanging production information with the suppliers means that they can provide additional raw materials as per requirements. This will ensure that there are no shortages or additional costs to production. Also, having long term contracts with suppliers ensures stable relationships between the organisations.

2.8.6 Customer Relationships

Customer relationships, like supplier relationships, are also externally focused, and the improvement programmes include: reliable and prompt deliveries, commercial actions to stabilize demand, capability and competence of sales network, early information on customer needs, flexibility on meeting customer requirements, service-enhanced product and customer involvement in product design (Panizzolo, et al., 2012). Customer involvement in design refers to all the firm-related actions that customers take part in that provide feedback, knowledge, and information to the firm, so as to improve the design of the product (Menguc, Auh, & Yannopoulos, 2014). This involvement is an important contributor to new product success as consumers bring a diversity of information which improves the quality of the end product (Salomo & Trommsdorff, 2003; Svendsen, Haugland, Gronhaug, & Hammervoll, 2011). Reliable and prompt deliveries of goods and services builds consumer trust. Early information on customer needs ensures that their needs are considered during manufacturing and production. In addition, engaging with the customers ensures that what is produced is what the customers want (Khusaini, et al., 2014).

The lean tool consists of a variety of best practices and improvement programmes from different areas of the company, which must be implemented by an organisation that aims to become lean. These areas include; supplier relationships, process and equipment, manufacturing planning and control, human resources, product design and customer relationships which have been discussed above (Panizzolo, et al., 2012). In order to become lean, these improvement programs are implemented at various areas as discussed in the following section.

2.9 Proposed Value Chain Conceptual Framework for a Craft Brewery

In this study, the hybrid conceptual framework was drawn from the works of Panizzolo et al. (2012) and Belhadi et al. (2016). Belhadi et al. provided a simple method to identify the starting points for lean management implementation. On the other hand, Panizzolo et al., emphasised that lean management is not only internally focused but also includes a focus on suppliers and customers. This model is favoured because of its detailed identification of lean activities and its positioning within an organisation to link both upstream and downstream activities.

The framework provided by Panizzolo et al., has been used by different researchers studying lean management implementation. These include Hu et al., (2015) and Kumar, Luthra, Govindan, Naveen, and Haleem (2016).

The proposed framework, as depicted in Figure 2.8, was adopted for this research. It combined the internal step-by-step procedure and accounted for the entire value stream by using lean improvement programmes for suppliers and customers. The purpose of this hybrid choice was to determine a framework that not only looked at the internal operations but the external operations as well. Combining the two models was the only modification that took place. All other factors of the different models are the same as the original frameworks. The framework is divided into three parts; upstream activities, internal activities and downstream activities. These form the value chain of the brewery.

Firstly, the upstream activities consist of the supplier related activities. Here, the best practices include; JIT deliveries, open orders, quality at the source, early information exchange on production plans, supplier involvement in quality improvement programmes, reduction of number of sources and distances, long-term contracts, total cost supplier evaluation and supplier involvement in product design and development (Panizzolo, et al., 2012).

Secondly, the internal activities consist of the lean elements which must be implemented by a company wanting to adopt lean practices. Here, the 'current state' of the firm is analysed using a lean tool – value stream mapping. Then in order to organise the house, improve the process and sustain this, other lean tools are also introduced. For organising the house, 5S and cellular manufacturing are implemented. For improving the process, Kanban, (SMED), quality control and TPM are implemented. In order to sustain these results, work standards, kaizen, and problem-solving tools are used (Belhadi, et al., 2016). Improvement areas for internal activities include the following: human resources, process & equipment, manufacturing planning & control and process design (Panizzolo, et al., 2012). These all provide feedback into the system as they assist in organising the house, improving the process and sustaining the results.

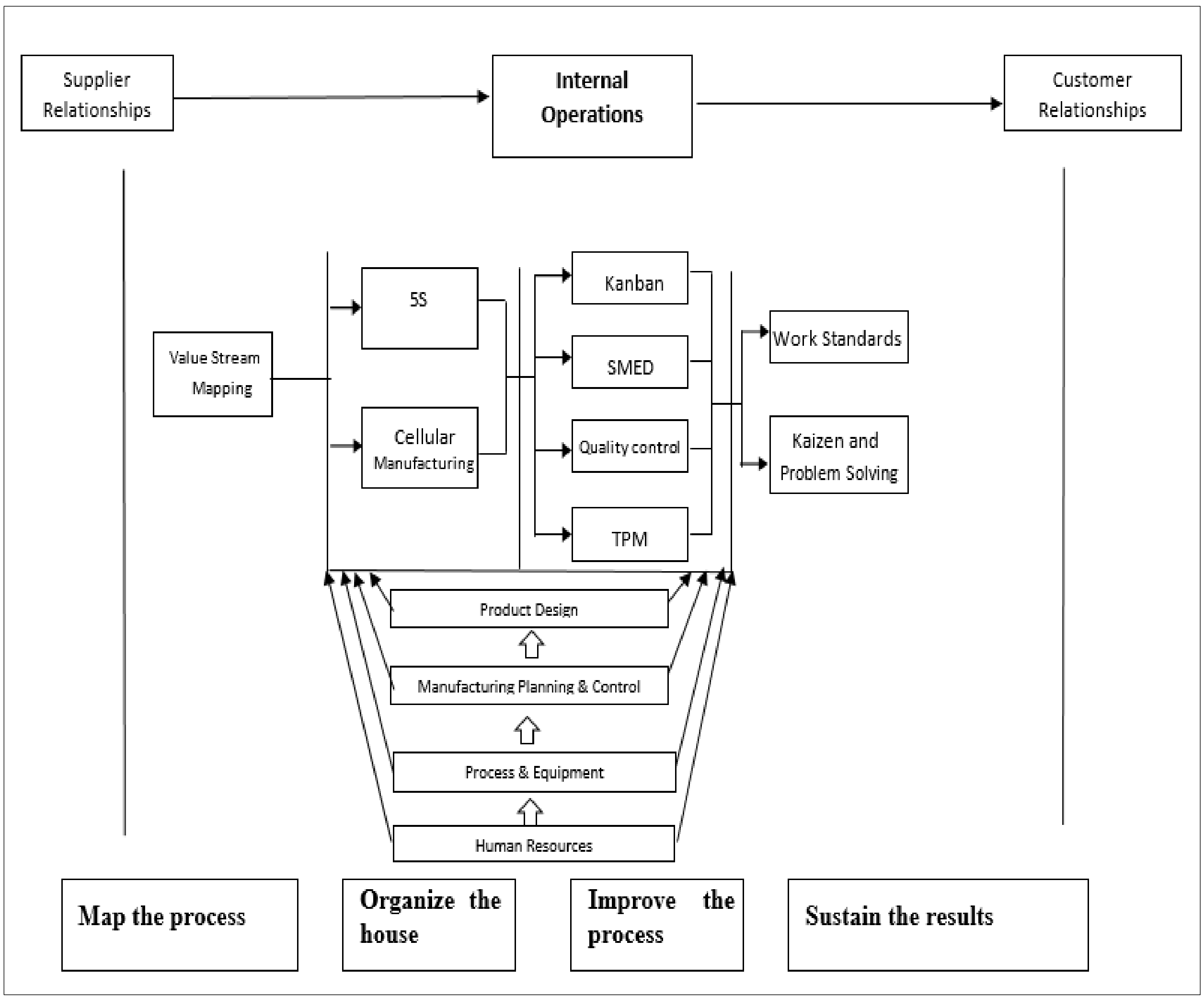


Figure 2. 8 Adapted Conceptual Framework

Source*: (Adapted by the the researcher)*

Thirdly, the downstream activities of the supply chain include the activities which deal with customer relationships. These best practices include quality at the source, reliable and prompt deliveries, commercial actions to stabilise demand, capability and competence of sales network, early information on customer needs, flexibility in meeting customer requirements, service-enhanced product, customer involvement in product design and customer involvement in quality programmes (Panizzolo, et al., 2012).

2.10 Application of the conceptual framework

Much research has been carried out with regards to the application and implementation of lean production methodologies in different industries as Alves et al., (2011), Raj et al., (2017) as well as Dhiravidamani et al., (2017).

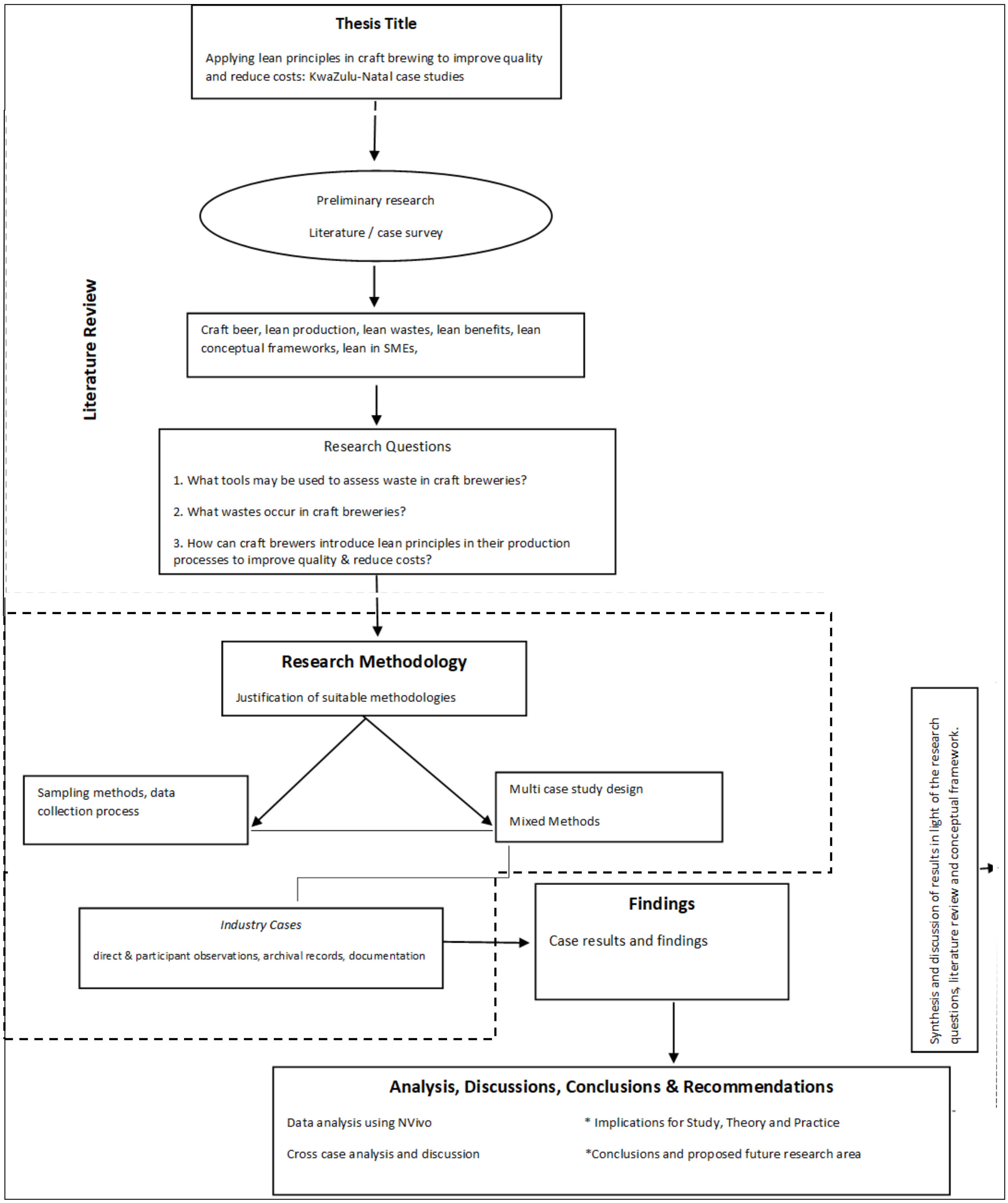
This framework was applied and tested by the researcher in the case study breweries. It was used as a guideline to assess the current state of the case study breweries and then to investigate the feasibility and challenges associated with trying to implement lean methodologies in order to improve efficiency. Furthermore, the framework assisted in suggesting organisation strategies for the beer production unit and proposing the implementation of lean elements that are applicable to this craft brewing industry. This framework may also be used by SMEs in small food and drink manufacturing companies.

2.11 Gaps in the literature

If lean plays a significant role in reducing waste, decreasing costs and improving quality and efficiency in any company as the lean guru assert, then it is beneficial for all firms across various industries to implement lean methodologies. Although there have been extensive studies on the implementation of lean methodologies and development of frameworks for certain industries, these frameworks, and lean implementation models, have not been tested rigorously in the craft brewing industry as there is very little literature on lean management in craft brewing. Most literature specific to this sector focuses on the growth of the industry and on marketing rather than on production management (Green, 2015). Therefore, it is the objective of this research to focus on the craft brewing industry, and specifically, to consider whether lean methodologies can be introduced effectively in a craft brewery and to identify what lean practices, tools, and techniques might be most applicable to this industry.

2.12 Chapter Summary

This chapter discussed the craft beer production process and looked at how lean principles, practices, tools, and techniques have been implemented in several industries through the examination of cases. In addition, the chapter explained the benefits of implementing the lean methodologies and provided some arguments against lean production. Furthermore, the chapter discussed which lean tools have been implemented by SMEs and critically identified the ones which could be used in small food and drink manufacturers, with special reference made to craft brewers. The following chapter discusses the research methodology and methods which were used to conduct this study.



Thesis Title
Applying lean principles in craft brewing to improve quality and reduce costs: KwaZulu-Natal case studies
Preliminary research
Literature / case survey
Literature Review
Craft beer, lean production, lean wastes, lean benefits, lean conceptual frameworks, lean in SMEs,
Research Questions
1. What tools may be used to assess waste in craft breweries?
2. What wastes occur in craft breweries?
3. How can craft brewers introduce lean principles in their production processes to improve quality & reduce costs?
Research Methodology
Justification of suitable methodologies
Sampling methods, data collection process
Multi case study design
Mixed Methods
Industry Cases
direct & participant observations, archival records, documentation
Findings
Case results and findings
Synthesis and discussion of results in light of the research questions, literature review and conceptual framework.
Analysis, Discussions, Conclusions & Recommendations
Data analysis using NVivo
Cross case analysis and discussion
* Implications for Study, Theory and Practice
*Conclusions and proposed future research area

CHAPTER THREE: METHODOLOGY

3.1 Introduction

Chapter Two reviewed the literature on lean methodologies and discussed lean principles, practices, tools, and techniques, also referred to as lean improvement programmes. The benefits of implementing lean management and the lean elements that are relevant for SMEs were highlighted, suggesting how SMEs can effectively implement lean. A conceptual framework was adopted for this exploratory study.

Chapter Three discusses the research methodology that was used to attain the objectives of this study. Polit and Beck (2004) stated that a research methodology describes how the study is structured and how data is systematically collected and analysed. De Vos, Strydom, Fouche and Delport (2005) added that the research methodology also describes the participants, population and data collection instruments.

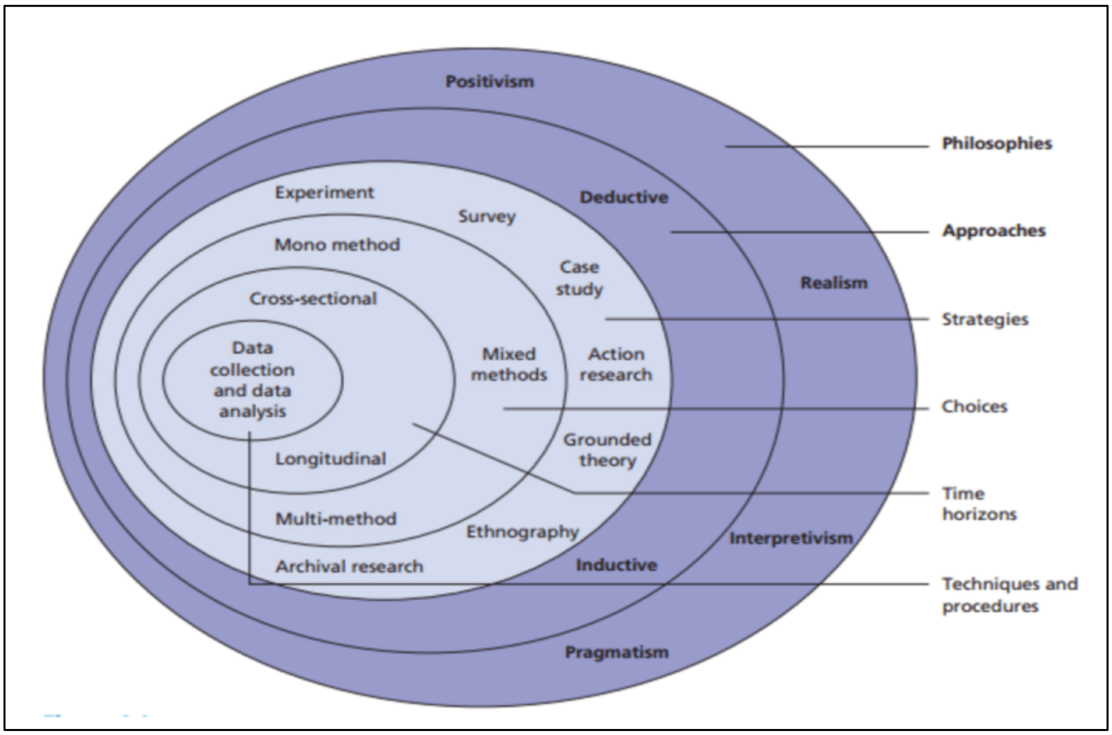


Figure 3. 1 Research Onion Analogy

Source*: (Saunders, Lewis, & Thornhill, 2016)*

The terminology used in research methodology, and the classification of concepts, differs between sources (Mkansi & Acheampong, 2012; Sahay, 2017). The research onion analogy suggested by Saunders et al. (2016) illustrates a typical range of choices and decisions made by the researcher. These include research philosophies, approaches, strategies, choices and time horizons, as well as techniques and procedures for data collection and analysis (Saunders, et al., 2016).

Figure 3.1 depicts the ‘research onion’, with the different decisions a researcher has to make. Developing the research methodology is also likened to “peeling the onion” from the outer layer until the middle is reached (Sahay, 2017). This analogy was used as a guideline to develop the research methodology applied in this study.

3.2 Research Purpose

Research is typically descriptive, explanatory or exploratory (Saunders, et al., 2016). A descriptive research design portrays an exact profile of an activity or a phenomenon, whilst an explanatory design aims to explain how and why a situation, case or condition was brought about and explains the causal relationships amongst the variables (Davies, 2003; Yin, 2014; Saunders, et al., 2016). Exploratory research is carried out to increase or gain new insights into a phenomenon in order to increase the breadth of knowledge about it (Burns & Grove, 2001; Saunders, et al., 2016).

This study was an exploratory study. It sought to assess the role of lean philosophy and to discover new insights and ideas about the application of lean production to the craft brewing industry. It explored the lean tools that may be used to assess waste in craft breweries, the sources of waste that might occur at craft breweries and finally how craft breweries could introduce lean principles in their production processes in order to improve quality and reduce costs.

3.3 Research Questions and Objectives

Mohrman and Lawler (2011) emphasised that for studies that aspire to impact organisational practice, the researcher should ask the following key questions when drafting the questions for the study being conducted;

a) How might my research impact organisational practice?
b) What kind of research questions should I ask?
c) How can the knowledge from my research reach and influence practitioners?
d) How should I conduct research if I want it to influence organisational practice?

For the study to impact organisational practice, the researcher should ask questions which will provide knowledge and be useful for practice. In addition, asking research questions which are aligned with practitioner concerns would have a greater impact on the organisations. Furthermore, the knowledge gained by the researcher from the study should be accessible to and shared with the practitioners. Pasmore (2013) states that when discussing the implications of the findings for practice, the following should be described: (i) the problematic issue(s) being addressed, (ii) the specific audience(s) to which implications are addressed, (iii) a small number of recommendations about what the practitioners should/could/should not do based on the research findings (iv) an expected outcome of carrying out recommendation(s) and (v) some specific illustrations of what carrying out the recommendations might look like.

Adhering to these suggestions as well as keeping in mind the research problem, the research questions which were formulated for this study were:

1. What tools may be used to assess waste in craft breweries?
2. What wastes occur in craft breweries?
3. Are lean principles appropriate for application in craft breweries and if so, how can craft brewers introduce lean principles in their production processes to improve quality and reduce costs?

The objectives of the study were formulated from these questions. The objectives of the study were:

1. To identify appropriate assessment tools that may be used to assess waste in craft breweries.
2. To identify any sources of waste that may occur in craft breweries.
3. To ascertain if lean principles were at all appropriate for craft breweries and if so, to determine how craft brewers can introduce lean principles in their production processes to improve quality and reduce costs.

3.4 Research Strategy

A research strategy is a plan that directs how an investigation will take place and how data will be collected and analysed (Blanche & Durrheim, 2002; Saunders, et al., 2016). The different types of research strategies include experiments, surveys, grounded theory, archival research, ethnography, action research and case study research (Saunders et al., 2016).

This research used a case study strategy. A case study is defined by Yin (2014, p. 16) as "*an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident".*

To determine whether the case study strategy was suitable for this study, the following case study assessment questions, as provided by Benbasat, Goldstein and Mead (1987) and cited and used by Iacono, Brown and Holtham (2011) were used:

1. Can the phenomenon of interest be studied outside its natural setting?
2. Must the study focus on contemporary events?
3. Is control or manipulation of subjects or events necessary or possible?
4. Does the phenomenon of interest enjoy an established theoretical base?

A case study research strategy was selected because the lean phenomenon being researched could not have been studied outside its natural setting and it required the study to focus on current events, which would not have been feasible to do using other designs, for example, experiments or surveys (Yin, 2014; Gustafsson, 2017). Again, other strategies, like the history design strategy would not have provided the focus on contemporary events and archival records would have provided a limited focus on those events (Yin, 2014). It was not necessary or possible to control the events being studied, as a researcher would with experiments. In addition, the literature on lean theory application to craft breweries is very limited. A case study approach was deemed suitable for all the above reasons.

Other studies looking at lean management which have used the case study design strategy include those by Rajenthirakumar et al. (2011), Jiménez et al. (2012), Rahman and Karim, (2013), Lacerda et al. (2016) and Dhiravidamani et al. (2017). All these studies sought to study a particular phenomenon and gain a better understanding of it.

The case study method helped to understand the topic more and in greater detail (Saunders, et al., 2016; Green, 2015). Rule and Vaughn (2011) add that case studies are very flexible in that they can be easily managed and are adaptable.

Some common misunderstandings about case study or multi-case study research, as stated by Flyvbjerg (2006) are that:

- Theoretical knowledge is more valuable than practical knowledge
- One cannot generalise from a single case, therefore the single case study cannot contribute to scientific development
- The case study is most useful for generating hypotheses, while other methods are more suitable for hypotheses testing and theory building
- The case study contains a bias toward verification
- It is often difficult to summarise specific case studies

These misunderstandings are addressed throughout the methodology chapter, so as to provide a clear justification on why case studies are valuable, can provide either literal or theoretical replications, can assist in theory building, can be verified and also how summarisation from case studies can be carried out.

Other researchers agree that these perceived disadvantages of case studies do not limit their usefulness as a research strategy (McCutcheon & Meredith, 1993; Stuart, McCutcheon, Handfield, & McLach, 2002; Yin, 2014). Case studies are a valid and essential tool in the range of available research designs (Flyvbjerg, 2006).

3.5 Case Study Research Design

The five components of a case study research design that guided this research, as noted by Yin (2014) and also used by Davies (2003), were:

1. A case study's questions
2. It's proposition, if any
3. Its unit(s) of analysis
4. The logic linking the data to the propositions
5. The criteria for interpreting the findings

3.5.1 Questions

The case study questions assisted in clearly defining the nature of the study (Davies, 2003; Yin, 2014). For this research, the case questions, formulated from the literature review, sought to address the problem of selecting the right lean elements in a craft brewery in order to reduce costs and improve quality. An additional question was how these lean elements would be introduced and implemented in a craft brewery.

3.5.2 Propositions

Propositions are used to direct the attention of the researcher on what needs to be studied and observed within the limitations and scope of the study (Yin, 2014). However, for exploratory studies, propositions might not be available as they might be the subject being explored. For such studies, the purpose of the study must be stated to provide the boundaries for the study (Davies, 2003; Yin, 2014). The purpose of this study was to:

- Identify appropriate assessment tools that may be used to measure waste in craft breweries
- Identify and measure any sources of waste that may occur in craft breweries
- Ascertain whether lean principles were applicable to craft breweries and determine how craft brewers can introduce lean methodologies based on lean principles in their production processes in order to improve quality and reduce costs

3.5.3 Unit of analysis

The meaning of the unit/s of analysis relates to the way in which the case study questions have been defined for the study (Davies, 2003; Yin, 2014). For this study, the unit of analysis was the individual craft brewery. Hence the study included the set of activities, equipment and human elements within that brewery that could be managed to reduce costs and improve quality.

3.5.4 Logic linking data to case study purpose

The logic of the case study shows what data is to be collected and what should happen to that data. This links the data to the proposition or purpose of the research and ensures that the analysis also achieves this purpose. Several analytical techniques allow the data to be linked to the purpose or propositions of the study. These include pattern matching, explanation building, time-series analysis, logic models and cross case analysis (Yin, 2014).

The first four techniques can be used with a single case study or multiple cases, whereas cross case analysis can only be used with multiple cases. This technique is suggested for a study that consists of at least two cases. This study used the cross-case analysis technique for linking the data to the purpose of the study because the analysis was easy and also robust (Yin, 2014).

For a study with a few cases, the cross-case analysis technique involves the use of word tables to present the data, as suggested by Yin (2014). The word tables that were used in this study contained the main findings. Data was gathered from the two breweries, presented seperately and then later merged. Data was analysed using Nvivo.

3.5.5 Criteria for interpreting case study findings

When conducting case study research, it is important to ensure that the analysis and interpretation of the data is of high quality (Yin, 2014). The four principles which underlie good research and must be addressed include the following (Yin, 2014):

- The analysis should indicate that all evidence was attended to
- The analysis should address all possible rival explanations
- The analysis should address the most significant aspects of the case study
- The researcher should use prior knowledge in the case study

To adhere to these, all evidence which was collected was presented, as shown in Chapter 4. Possible rival explanations were addressed in chapters 2 and 5. The most significant aspects of the study were highlighted and discussed and finally, the researcher used prior knowledge to assist in the analysis. The case study procedure shown below was followed and integrated with other aspects of the research methodology.

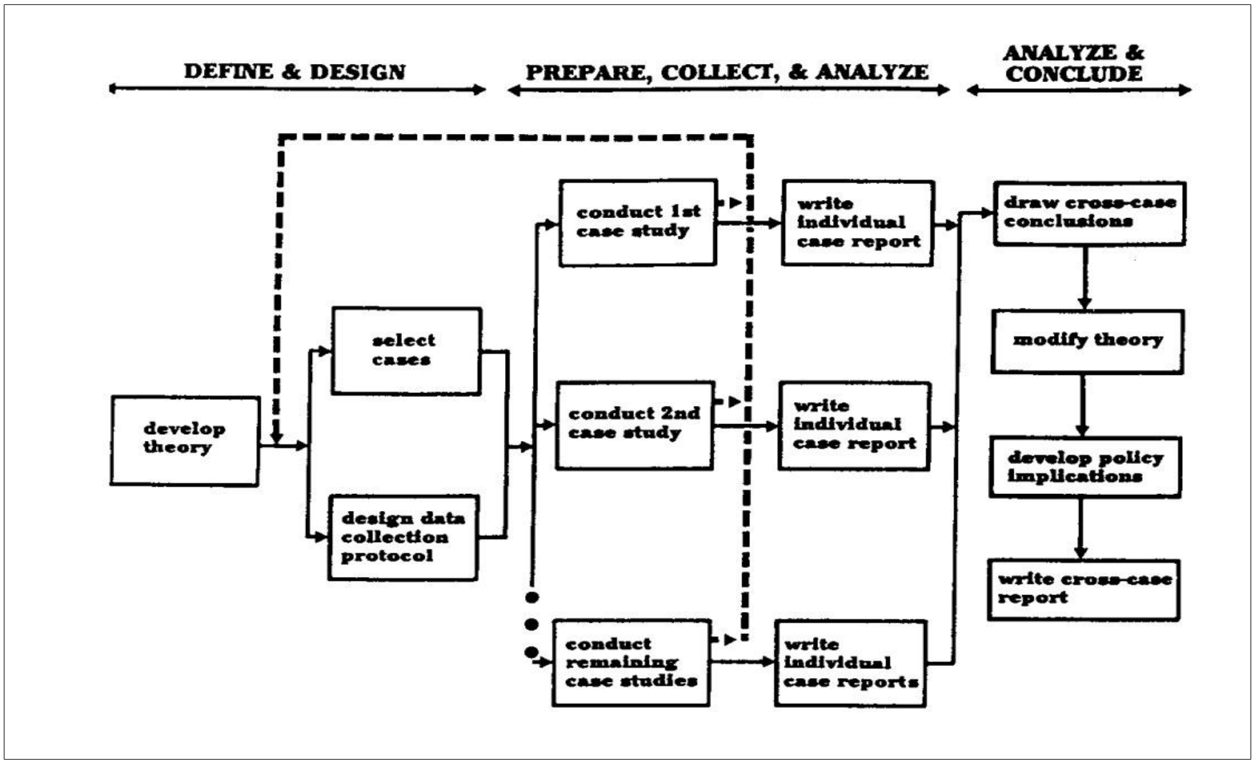


Figure 3. 2 Case Study Procedure

Source: (*Yin, 2014)*

The case study procedure shown in Figure 3.2 is divided into three parts: (1) definition & planning, (2) preparation, collection & analysis, (3) analysis & conclusion. The literature review discussed lean theory and a selection of the cases was made, as discussed below. Data was collected using five collection methods; interviews, documentation, archival records, direct observation and participant observations (Yin, 2014; Nickel, Ferreira, Forcellini, Batista, & Buch, 2015).

The results and findings from each case study are presented in Chapter 4. Chapter 5 provides an analysis of cross-cases and builds on and discusses the implications of this research in terms of theory and in practice.

3.6 Selecting cases

The logic used in selecting cases is different from the logic used in statistical sampling. Statistical sampling seeks samples that are representative of the population, whereas cases are selected in order to replicate or extend a developing theory or to fill theoretical categories (Meyer, 2001).

Yin (2014) emphasises that replication, not sampling logic, is used for multi-case studies. Each case is selected for either: i) a literal replication or ii) a theoretical replication

Literal replication predicts similar results whereas a theoretical replication predicts results that are different, but for anticipated reasons. With literal replications, two to three cases are used whilst four to six cases or more may use theoretical replication logic (Yin, 2014).

This study selected cases for literal replication logic. Literal replication produces more of the same outcomes, which provide reassurance that the results are typical. Since two to three cases are suggested for replication (Yin, 2014), this study selected two cases in KwaZulu-Natal that were readily accessible to the researcher. The researcher had initially e-mailed three breweries and got responses from two breweries, which were subsequently chosen as the case studies.

3.7 Research Paradigm

The three broad research paradigms are qualitative, quantitative and mixed methods. Quantitative methods describe a research technique for gathering and analysing data that uses numbers whilst a qualitative method describes one that uses words. Mixed methods refer to combining both qualitative and quantitative approaches in one study (Saunders, et al., 2016; Onwuegbuzie & Combs, 2011).

Kyeyune (2010, p. 41-43) cited definitions of mixed methods from several sources:

- "*those designs that include at least one quantitative method (designed to collect numbers) and one qualitative method (designed to collect words), where neither type of method is inherently linked to any particular inquiry paradigm"* (Greene, Caracelli & Graham, 1989).
- " *the collection or analysis of both quantitative and /or qualitative data in a single study"* (Creswell, Plano Clark, Gutman & Hanson, 2003)
- "*the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques*" (Johnson, Onwuegbuzie & Turner, 2007).

From these definitions, it is clear that mixed methods use words (qualitative) and numbers (quantitative) to gather, combine and/or analyse data. A similar study to this was conducted in the paint industry, where lean methodologies were implemented and a case study strategy was also used with a mixed methods approach for data collection (Rajenthirakumar, et al. 2011).

Similarly, Donadini and Porretta (2017) used mixed methods to conduct a study in the craft beer industry. In their study, they explored the quality perceptions that consumers of craft-beer had and the factors that made the drinkers interested in craft beer. A combination of qualitative and quantitative methods was used to collect and analyse data.

Mixed methods designs can be either emergent or fixed. With emergent mixed design, the usage of a mixed method is a result of the circumstances that arise during the research process. This means that initially, the researcher would have selected one research design (qualitative or quantitative) with the other method then used during the research process as a result of an unforeseen deficiency in the original plan. On the other hand, fixed mixed methods are decided upon before the research is conducted (Molina-Azorin & Cameron, 2010; Creswell & Plano Clark, 2011). This study used a fixed mixed method as the design was determined before the research was conducted.

There are several reasons why researchers use both quantitative and qualitative methodologies, i.e. mixed methods, in a study. Some of the main reasons, as stated by O'Cathain, Murphy, & Nicholl (2007) and Tariq & Woodman (2013) include:

- Complementarity
- Expansion
- Development
- Initiation
- Triangulation

Mixed methods do not replace, change or substitute qualitative and/or quantitative research designs, but draw on the advantages of the two designs (Vosloo, 2014). This research employed mixed methods because of complementarity (the usage of data collected by one method to explain the results from another method), development reasons (the use of results from one type of data method to enlighten or inform the development of another) and triangulation reasons (the use of several methods to support one another) (O'Cathain, Murphy, & Nicholl, 2007; Tariq & Woodman, 2013).

The rationale for selecting mixed methods research design for this study was (Vosloo, 2014):

- To gain a better understanding so as to have a full research picture
- To attain deeper and broader insights about the case study breweries
- To gain more data about a wider range of the case elements
- To improve the collaboration and interpretation of results and findings from the cases
- To clarify the underlying logic and concept

3.8 Research Location

The research was conducted at locally-owned breweries located in the province of KwaZulu-Natal, South Africa.

3.9 Data collection

The choice of data collection methods selected is crucial as it must be compatible with the overall research strategy (Creswell, 2003; Stone & Harris, 1984; May 2006). The available case study data collection techniques include documentation, archival records, interviews, direct observations, participant observation and physical artifacts (Yin, 2014; Houghton, Casey & Smyth, 2017).

Table 3.1 provides a list of the strengths and weaknesses of using each source, as well as some examples of the sources of evidence.

Table 3. 1 Sources of case study evidence

Source of Evidence	**Strengths**	**Weaknesses**	**Examples**
Documentation	*Stable* – can be reviewed repeatedly *Unobtrusive* – not created as a result of the case study *Specific* – can contain the exact names, references, and details of an event *Broad* – can cover a long span of time, many events, and many settings	*Retrievability* – can be difficult to find Biased selectively, if collection is incomplete Reporting bias – reflects (unknown) of any given document's author Access – may be deliberately with held	Letters, memoranda, e-mails Agendas, announcements News clippings in mass media or community news, etc.

Archival records	(same as those for documentation) Precise and usually quantitative	(same as those for documentation) Accessibility due to privacy reasons	Public records, Service records Organisational records Survey data Charts, etc.
Interviews	Targeted – focuses directly on case study topics Insightful – provides explanations as well as personal views	Bias due to poorly articulated questions Response bias Inaccuracies due to poor recall Reflexivity – interviewee gives what interviewer wants to hear	Unstructured interviews In-depth interviews
Direct Observations	Immediacy – covers actions in real time Contextual – can cover the case's context	Time consuming Selectivity- broad coverage difficult without a team of observers Reflexivity- actions may proceed differently because they are being observed	Observing meetings, sidewalks, factory-processes
Participant observation	(same as above for direct observations) Insightful into interpersonal behaviour and motives	(same as above for direct observations) Bias due to participant-observer's manipulation of events	having key interactions with people
Physical Artifacts	Insightful into cultural features Insightful into technical operations	Selectivity Availability	A tool A work of art, etc.

Source: *(Adapted from Yin, 2014)*

In this study, data was gathered using interviews, documentation, archival records, direct observation and participant observation.

3.9.1 Interviews

Interviews can be considered to be structured, semi-structured or unstructured (Saunders, et al., 2016; Yin, 2014). The following table provides the various uses of each type of interview in relation to different research purposes.

Table 3. 2 Uses of different types of interview for each research purpose

	Exploratory	Descriptive	Explanatory
Structured		√√	√
Semi-structured	√		√√
Unstructured	√√		

√√ = *more frequent* √ = *less frequent*

Source*: (Saunders et al., 2016)*

For exploratory research, semi-structured and unstructured interviews are suitable. Interviews are conducted to find out about elements which cannot be directly observed (Belova & Yansong, 2008). This study used semi-structured interviews with three craft brewing experts, to gain a better understanding of the craft brewing processes, current industry challenges, quality problem areas and the possibilities of cost reduction in the production process. Two of the brewing experts were the respective brew masters of the two case study breweries and the third was a brewing consultant familiar with both of the breweries. An interview guide was used (Appendix A), which allowed the researcher to narrow down themes and formulate specific questions related to the research problem (Saunders, et al., 2016; Rabionet, 2009). The rationale for these interviews with craft brewing experts was that the researcher is not a brewing scientist. Therefore, for the researcher to understand the management of a craft brewery, the technical constraints and other issues concerning craft brewing, interviews were conducted. The brewing experts were made aware that they could ask for more information on the terminology used, if it was unclear or familiar.

The semi-structured interview guide included questions which:

- aimed to understand the processes involved in craft brewing, such as milling, mashing, etc, to gain a better understanding of the brewing process

- probed the critical stages of beer production that are of utmost importance in the production of good quality beer.
- identified measures that should be put in place to produce good quality beer.
- evaluated the processes that consumed substantial production resources and determined if there was anything that can be done to reduce the use of these resources.
- sought to identify the current challenges faced by the craft beer industry
- probed the likelihood of improvements that might have to be made in the production process in order to reduce the overall cost of production.

A digital voice recorder was used to record the responses of the participants and subsequently, the brewing consultant who was interviewed, also provided written responses to the interview questions (see Appendix C).

3.9.2 Documentation and Archival Records

Documentation and archival records refer to company records and typically include letters, e-mail, agendas, news clippings for documentation, as well as service records, organisational records, maps and charts, survey data, lists of names and personal records from archival records (Yin, 2014). Archival records and documents are not created for the case study, but rather exist on their own and provide the data required for case study research. Depending on the nature of the case and/or the nature of the records, the importance of these records will differ from study to study. In addition, archival records and documents offer a broad coverage of topics and they can be reviewed as many times as is deemed necessary (Yin, 2014). The archival records and documentation used were provided to the researcher by the case companies. The records and documentation included past brewing schedules and brewing history information, maintenance schedules, customer information as well as supplier information. Relevant information was extracted and used, in conjunction with the results from observations, to complete the research data collection forms.

3.9.3 Direct and Participant Observation

Observation allows for a systematic description of what is being watched and studied, making use of the five senses. (Stone & Harris, 1984; Kawulich, 2005). Direct observation allowed for the structured observation of the activities and observational instruments to be developed (Yin, 2014;

Thomas, 2001). Participant observation, which is also referred to as unstructured observation, allowed the researcher to play the role of ‘observer as participant’ as shown in the figure below.

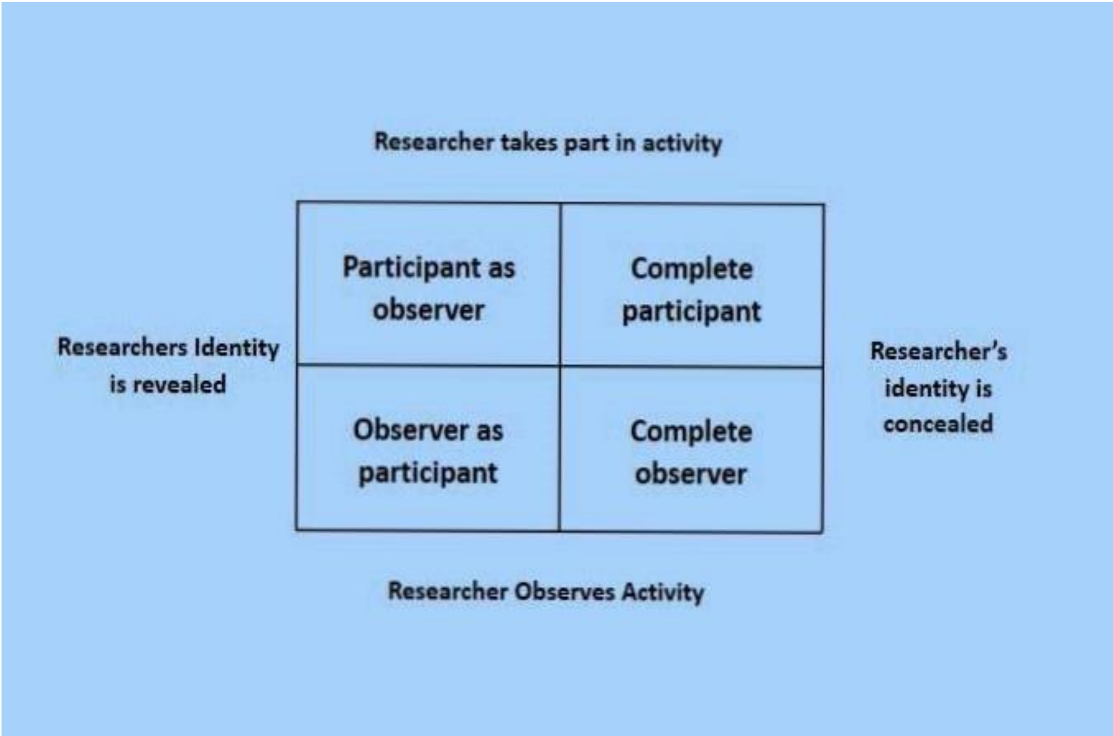


Figure 3. 3 Researcher Roles

Source*: (Saunders et al., 2016)*

The researcher can either be a ‘participant as observer’ where the researcher’s identity is revealed and the researcher takes part in the activity being observed or an ‘observer as participant’ where the identity of the researcher is revealed and the researcher only observes the activity. (Saunders, et al., 2016).

On the other hand, the researcher can be a ‘complete participant’ where the identity of the researcher is concealed, but the researcher also takes part in the activity, or a ‘complete observer’ where the identity is concealed, and the researcher observes the activity (Saunders, et al., 2016).

In this study, the role of ‘observer as participant’ was undertaken. In addition the researcher’s identity was revealed. The data was gathered using pre-structured observational instruments; a lean assessment tool (LAT) and a lean feasibility tool (LFT).

3.10 Development of the observation tools

The knowledge gained from the literature review assisted in developing the observational instruments that were used for this research.

3.10.1 Observation sheet construction

The current state tool (CST) was constructed to observe and record the current situation at the brewery. To do so, the process flow diagram, including materials, machinery, manpower, defects, errors, and inefficiencies at the brewery were recorded. Information required to conduct value stream mapping was also recorded, as discussed in the literature review. The observation wording, sequence and response choice were also considered here. In constructing this tool, the literature review was used to determine what to observe when drawing the process flow diagram and what to observe and record when conducting the value stream map analysis. This tool is shown as Appendix B, Section A.

Appendix B, Section B, 3 shows the lean assessment tool (LAT). This was adapted by the researcher from Panizzolo et al., (2012). It assessed the extent to which the brewery had adopted or was using lean principles. A Likert-type scale was used to assess the extent of each principle included in the LAT.

A Likert-type scale is made up of statements that explain and describe what is being measured or observed (Warmbrod, 2014; Mellor & Moore, 2013). The usual scale-types are 5- or 7-point scales (Sullivan & Artino, 2013).

This research used a 5-point scale to assess the extent to which the case study breweries had adopted or used lean principles. The minimum score 1, indicated no evidence or non-usage, and the maximum score of 5 indicated that the principle was used or applied to a very large extent. Scores 2, 3 and 4 indicated that the lean principle was used to a small extent, to some extent or to a moderate extent, respectively. Figure 3.4 shows a section of the LAT to illustrate the way in which the Likert scale was used.

Using the scale 1= not at all, 2 = to a small extent, 3= to some extent 4 = to a moderate extent, 5= to a large extent, please indicate a response to the following statement, by circling around the number.

TO WHAT EXTENT HAS THE BREWERY ADOPTED OR IS USING THE FOLLOWING LEAN PRINCIPLES?

	Process & Equipment					
		Not at all	**To a small extent**	**To some extent**	**To a moderate extent**	**To a large extent**
PE1	Set up time reduction	**1**	**2**	**3**	**4**	**5**

Figure 3. 4 Extract from Lean Assessment Tool

Thirdly, the lean feasibility tool (LFT) shown in Appendix B, Section B, 4, was also constructed from Panizzolo et al. (2012). A Likert-type scale was again used and assesses how feasible it would be to make changes and improve or implement the respective lean principles in the craft brewery, under the current production capabilities. Figure 3.5 illustrates how the lean feasibility tool was presented.

Using the scale 1=very difficult, 2=difficult, 3=neutral, 4=easy, 5=very easy, indicate a response to the following statement, by circling around the number.
HOW FEASIBLE WILL IT BE TO MAKE CHANGES TO AND IMPROVE OR IMPLEMENT THE DIFFERENT LEAN PRINCIPLES?

	Process & Equipment					
		Very Difficult	**Difficult**	**Neutral**	**Easy**	**Very Easy**
PE1	Set up time reduction	**1**	**2**	**3**	**4**	**5**

Figure 3. 5 Extract from Lean Feasibility Tool

3.10.2 Pretesting of observational tools

After the observational forms were constructed, they were pretested at Brewery A in order to refine the observation instruments and attain an easy understanding and consistency of the processes being observed.

3.10.3 Final version of observation sheet

The final versions of the observation forms were constructed after relevant changes were made to the observational tools. These were then used as the final data collection tools.

3.10.4 Data Collection Plan

To collect data systematically, the following data collection procedure, shown in Figure 3.6, was used. Firstly, the observations for the current state assessment (CSA) were carried out. A process flow diagram of the brewery was drawn, depicting the layout and the processes involved in brewing, and the inputs and the equipment used. A value stream map was drawn, following the steps discussed in the literature review. Distances, set up times, activity times and wastes were all identified in this step.

Thereafter, an assessment of the extent to which lean principles were being applied was made using the LAT. The next step was to conduct a feasibility assessment, using the LFT, to assess the feasibility of implementing the various lean principles under existing production capabilities. The final product of this exercise was to have a schedule or time frame for lean implementation.

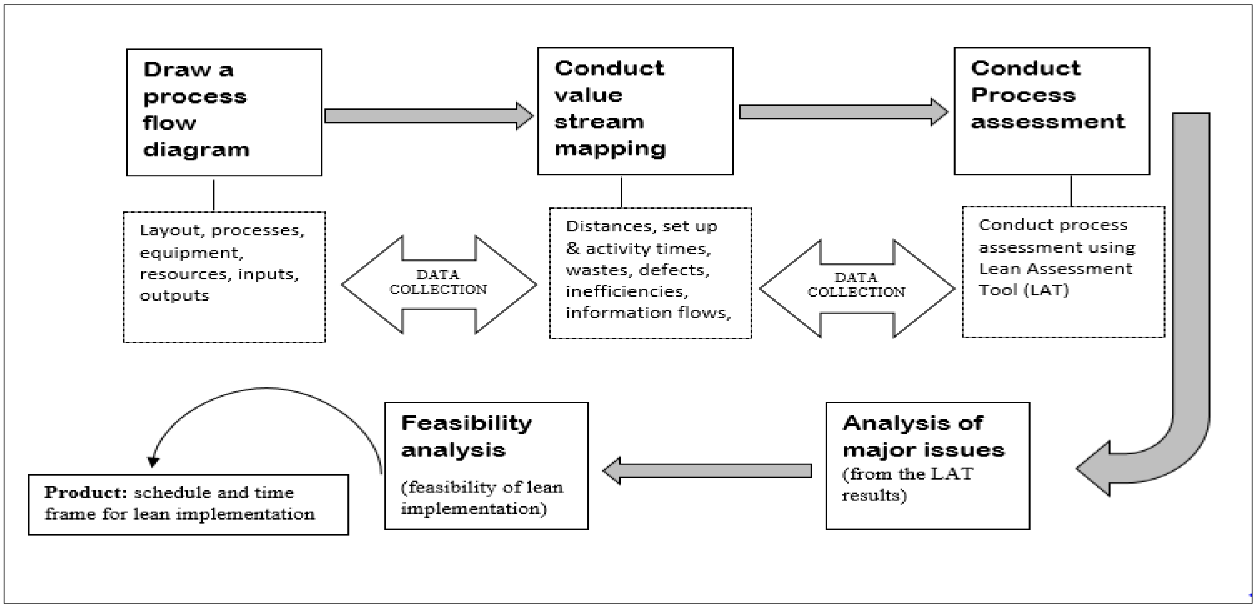


Figure 3. 6 Data Collection Procedure

Source*: (Researcher*)

3.11 Data Analysis

Data analysis refers to the way the researcher intends to arrange the data gathered in a meaningful way (Bernard, 2010). As noted, this research followed a mixed method design and therefore both quantitative and qualitative data were analysed.

Although Creswell & Plano Clark (2007) state that quantitative data is analysed using quantitative methods and qualitative data using qualitative methods, Onwuegbuzie and Combs (2011) argue that mixed analysis also encompasses analysing one single data type using first one analysis technique and then another, as is carried out during content analysis when qualitative data is organised into codes (qualitative analysis) and then the counts of the codes are analysed quantitatively.

In combining and integrating data, the researcher selected a specific mixed method design from the six major designs. The six main designs of mixed methods are; convergent parallel design, the explanatory sequential design, the exploratory sequential design, the embedded design, the transformative design and the multiphase design (Creswell & Plano Clark, 2011; Subedi, 2016).

This research used a convergent parallel design. The convergent parallel design, as described by Creswell & Plano Clark (2011) entailed;

1. Collecting quantitative and qualitative data at about the same time
2. The analysis of the results separately and finally
3. Merging the data to interpret the results

Quantitative data and qualitative data were analysed concurrently and the results and findings were merged and interpreted as one data set. Onwuegbuzie & Combs (2011) suggested the following steps for data analysis: data reduction, data display, data transformation, data correlation, data consolidation, data comparison and data integration.

Some of these steps were either omitted because they were irrelevant, e.g. data correlation, or merged and conducted simultaneously for this research, e.g. data consolidation, comparison and integration. Data correlation was irrelevant because there were no linear relationships being compared. Other steps were conducted simultaneously because the content analysis process integrates.

3.11.1 Data reduction

Data reduction is the process of reducing the size or magnitude of data through various summarizing techniques (Onwuegbuzie & Combs, 2011; Johnson, 2014). In reducing quantitative data, data from the lean assessment tool was recorded and analysed using NVivo. Elements in the LAT that scored above 3 were identified. These are explained in chapter 5.

Qualitative data was reduced using NVivo software. Data from the interviews were transcribed and then reduced using NVivo software.

The stages which were used to develop this project in NVivo are demonstrated in table 3.3, as suggested by O'Neill (2013).

Table 3. 3 Stages of analysis using NVivo

Analysis stages using NVivo	**Processes involved in each stage**
1. Descriptive	Project details and research design Inputting sources Assigning attributes Creating values

	Creating classifications
2. Topic	Finding the obvious topics Creating initial nodes
3. Analytic	Merging nodes into hierarchies Sets Models and relationships Using Queries Running Queries Matrix coding queries Cross case queries analysis
4. Conclusions	Verification Developing theories

Source: *(O'Neill, 2013).*

The first stage involved entering the project details and data into NVivo. The researcher entered the interview schedules, journal articles and field notes. These were entered into NVivo sources and contained the sub-sections of internals, memos and externals.

Secondly, topics were extracted from the transcripts. Coding in NVivo allowed the grouping of related concepts to be organised in containers called nodes. Nodes are the themes or topics from the sources.

This analytical process allowed the researcher to define concepts and relationships within the data. The analysis which took place involved the merging of the nodes and then running queries like word frequencies, creating word clouds, text queries, etc., to determine what words appeared or were used the most. This made it possible to identify the common answers (words) that were provided by the respondents.

3.11.2 Data display

Data may be displayed visually by using tables and graphs for quantitative data, graphs, matrices, charts, networks, rubrics for qualitative data and then combining these two data sets in tables and graphs (Johnson, 2014; Onwuegbuzie & Combs, 2011). Graphs and charts were used to display the data for this research.

3.11.3 Data transformation

Data transformation in the context of this study referred to a process where qualitative data were converted to narrative data or narrative data were converted to qualitative data (Johnson, 2014; Onwuegbuzie & Combs, 2011). Qualitative data gathered from the CSA, LAT, and LFT were transformed to narrative data. In addition, some aspects of the secondary quantitative data gathered from the archival records and observation forms were transformed into qualitative data.

3.11.4 Data consolidation, comparison and integration

Data consolidation or merging combined both the qualitative and secondary quantitative data to generate combined sets of data suitable for answering the research questions. Data comparison allowed for data to be compared in order to provide confirmation of relationships. Finally, data integration allowed the quantitative and qualitative data to be combined into an overall analysis of the brewery operations (Onwuegbuzie & Combs, 2011). Data from the CSA were combined with data from LAT and LFT. These data were then interpreted as one set, as suggested by the case study protocol discussed earlier in section 3.5.

3.12 Credibility of Research Findings

One of the biggest criticisms of case study-based research is that it lacks thoroughness and exhaustiveness. However, some researchers argue that this criticism is invalid (McCutcheon & Meredith, 1993; Stuart, McCutcheon, Handfield & McLach, 2002; Yin, 2014). To demonstrate the rigour of this research, several tests were applied; reliability, construct validity, and external validity, which were applicable to an exploratory study (Yin, 2014), as shown in the table below.

Table 3. 4 Tests and tactics for exploratory case-based research

Tests	Case study Tactic	Phase of research in which tactics occur
Construct Validity	• Use multiple sources of evidence • Establish chain of evidence	Data collection Data collection
External	• Use replication models in multi-case studies	Research design

Validity		
Reliability	• Use case study protocol • Develop case study database	Data collection Data collection

Source: *(Adapted from Yin, 2002)*

3.12.1 Construct Validity

Construct validity refers to the formation of the right operational measures for the concepts that are being studied (Yin, 2002; Voss, Tsikriktsis & Frohlich, 2002; Stuart, et al., 2002). To avoid construct invalidity, the study used multi sources of evidence and discussed how evidence was gathered from interviews, archival records, documentation, direct observations and participant observations, secondly, a chain of evidence from the data collected clearly showed how the data were collected and from where.

3.12.2 External Validity

External validity refers to the establishment of the extent to which the findings of the case can be generalised beyond the case study in question. It is important to emphasise that case studies provide analytical generalisations, whilst a survey provides statistical generalisations, i.e. generalisations to a population. Analytical generalisations from a case study design are from the case study(s) to the broader theory of the phenomenon being studied and not from the selected sample to the population (Stuart, et al., 2002; Yin, 2014). Furthermore, Maxwell and Chmiel argue that findings from cases can also be transferable. Transferability of findings and results from case study research involves knowledge being transferred from a study to a new situation (Maxwell & Chmiel, 2014).

Yin (2014) and Voss et al., (2002) suggest that to improve external validity, research can be replicated. In this research, cases were selected for literal replication, which allowed for the selection of two cases that were expected to produce similar results. If this proves true, it suggests that the results are generalisable to further, similar cases.

3.12.3 Reliability or trustworthiness

Reliability refers to the degree to which the research data collection and analyses methods produce consistent findings (Saunders, et al., 2016). Threats to reliability included observer error and subject error. (Easterby-Smith, Thorpe, Jackson & Lowe, 2008; Saunders, et al., 2016). To enhance reliability, two tactics were used: using a case study protocol and having a case study database. The same research protocol or format was used for both the cases. A database was created to easily store and retrieve information. Observer bias and error were reduced by using pre-structured data collection methods. In addition, the observer effect was reduced by maintaining minimum interaction in the brewery and keeping in the background. In addition, to test the reliability of the instrument, a pre-test was carried out so as to easy understanding and consistency of the process being observed.

3.12.4 Research Audit Trail

The audit trail is a description of the steps taken during the research, from the start to the end. It includes records regarding what has been done in the study. The audit trail adds methodological rigour to the study as it demonstrates a clear series of events that led to the completed analysis (Carcary, 2009).

Lincoln and Guba (1985) as cited by Carcary (2009) as well as Cohen and Crabtree (2006), suggest six categories for reporting information when developing an audit trail. These are shown in table 3.5.

Table 3. 5 Audit Trail Categories

Audit Trail Category	Examples
Raw data	raw data, written field notes, unobtrusive measures (documents
Data reduction and analysis products	summaries such as condensed notes, unitized information and quantitative summaries and theoretical notes
Data reconstruction and synthesis products	structure of categories (themes, definitions, and relationships), findings and conclusions and a final report including connections to existing literatures

	and an integration of concepts, relationships, and interpretations
Process notes	methodological notes (procedures, designs, strategies, rationales), trustworthiness notes (relating to credibility, dependability and confirmability) and audit trail notes
Materials relating to intentions and dispositions	inquiry proposal, personal notes (reflexive notes and motivations) and expectations (predictions and intentions
Instrument development information	pilot forms, preliminary schedules, observation formats

Source: *(Adapted from (Carcary, 2009; Cohen & Crabtree, 2006)*

Following these categories as a guideline, an audit trail was preserved for this research.

The step by step map which was used to gather data is shown as in Figure 3.4. In total, three semi-structured interviews were conducted. With regards to the observations, the observational schedule was first tested in one brewery, modified and a final version was then constructed. In total, eight observational exercises took place at brewery A and four at brewery B. The first two visits to brewery A were pilot visits to the brewery. The interview transcripts, observational schedules, records, documentation, memos and notes were used in arriving at the results and findings. The semi-structured interview guide, the CAS observational schedule and the LAT and LFT that were used, are presented in appendices A and B respectively.

3.13 Ethical Considerations

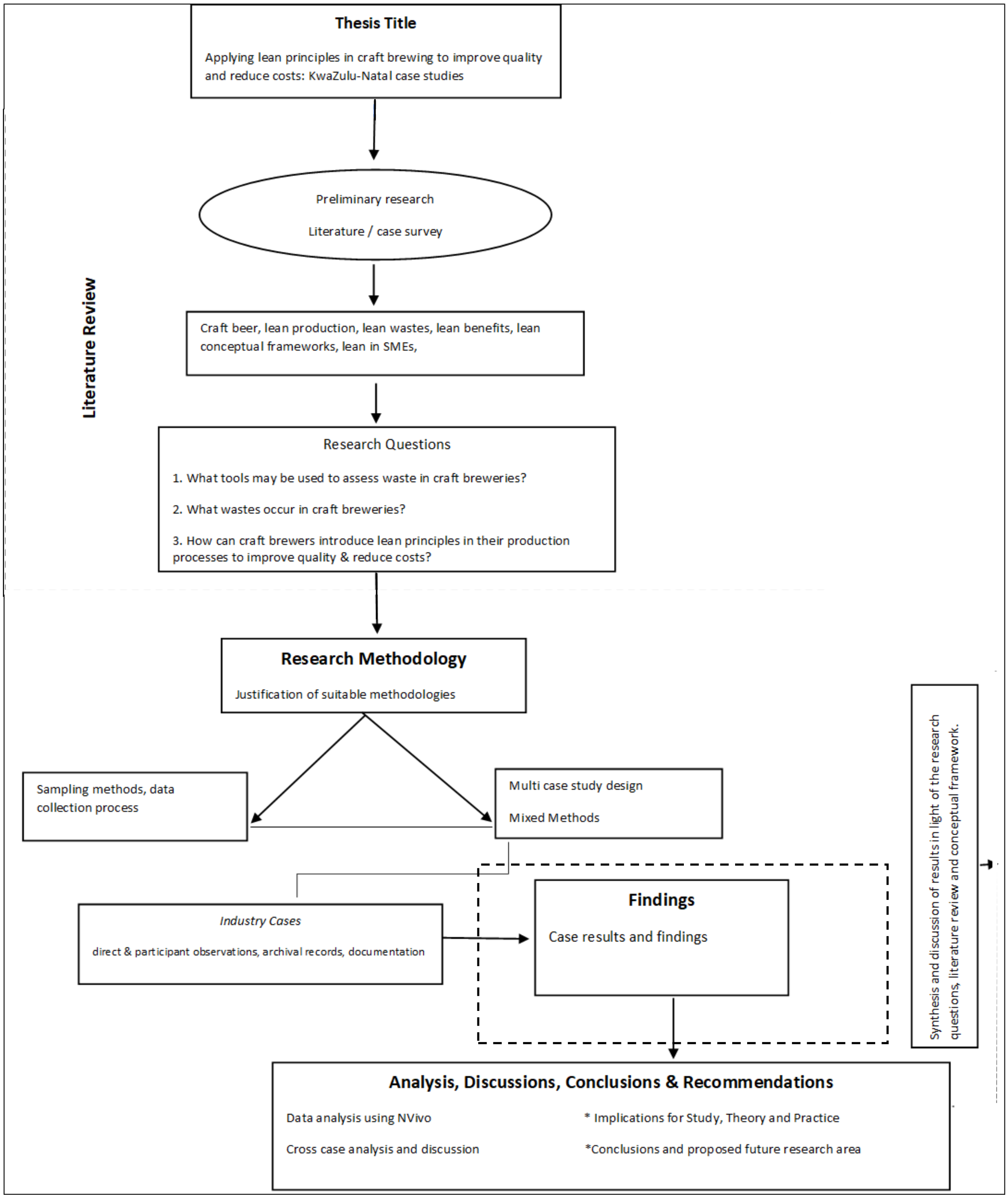
To carry out this research, the researcher acquired ethical clearance from the University of Kwa-Zulu Natal. This research observed rights to anonymity and confidentiality. Informed consent forms were issued out to the case study representatives, as well as the experts. Before the interviews, the purpose of the study was explained. Assurance provided on confidentiality was, whilst at the same time soliciting their consent. The participating breweries were made aware that their participation was voluntary. In addition, they were informed that they could withdraw from the study at any time without any monetary penalty or negative effects on their businesses.

3.14 Limitations of the Study

A limitation of the proposed research is that the investigation was confined to two craft breweries that may not be fully representative of the craft brewery industry in South Africa. A further potential limitation was that some of the information from the records and documentation was missing, for example, maintenance schedule dates and raw materials delivery dates.

3.15 Chapter Summary

Chapter three provided a discussion of the research methodology which was used in this study. This exploratory study followed a multi-case study, mixed method approach. The data was gathered via instruments of semi-structured interviews, direct observations, participant observation, documentation and archival records. The results and findings were presented and analysed using the NVivo software. The extent of the validity and reliability were discussed, stipulating their importance for case studies. The limitations of this study were provided as well as a discussion of ethical considerations for the study. The following chapter presents the findings and results of the study.


Thesis Title
Applying lean principles in craft brewing to improve quality and reduce costs: KwaZulu-Natal case studies
Preliminary research
Literature / case survey
Literature Review
Craft beer, lean production, lean wastes, lean benefits, lean conceptual frameworks, lean in SMEs,
Research Questions
1. What tools may be used to assess waste in craft breweries?
2. What wastes occur in craft breweries?
3. How can craft brewers introduce lean principles in their production processes to improve quality & reduce costs?
Research Methodology
Justification of suitable methodologies
Sampling methods, data collection process
Multi case study design
Mixed Methods
Industry Cases
direct & participant observations, archival records, documentation
Findings
Case results and findings
Synthesis and discussion of results in light of the research questions, literature review and conceptual framework.
Analysis, Discussions, Conclusions & Recommendations
Data analysis using NVivo
Cross case analysis and discussion
* Implications for Study, Theory and Practice
*Conclusions and proposed future research area

CHAPTER FOUR: RESULTS

4.1 Introduction

Chapter One presented the background to this study and introduced the research problem of selecting and implementing the right lean elements in a craft brewery in order to reduce costs and improve quality. This research problem is the foundation of the study. In Chapter Two, a review of the lean production literature was presented; specifically, lean principles, tools, techniques, practices, improvement programmes and lean wastes. The lean tools for small and medium sized enterprises were also discussed. A conceptual framework adopted for this research was prepared from the literature review.

Chapter Three discussed the research approach and the research methods and methodology used to achieve the objectives of this study. The following table provides a summary of the research methodological choices which were taken for this research.

Table 4. 1 Summary of the Research Methodology and Methods

Research Component	**Description**
Research Purpose	An exploratory study
Research Strategy	Multi-case study design
Research Paradigms	Mixed methods
Data Collection	Semi-structured interview, direct observation, participant observation, documentation and archival records
Data Analysis	NVivo software package
Credibility: Validity and Reliability	Construct validity, external validity & reliability

Source: *(Researcher)*

The research questions which the study sought to answer were:

1. What tools may be used to assess waste in craft breweries?

2. What wastes occur in craft breweries?
3. Are lean principles appropriate for application in craft breweries and if so, how can craft brewers introduce lean principles in their production processes to improve quality and reduce costs?

This chapter presents the findings of the study based on the data collected. The interviews with craft brewing experts enabled the researcher, who is not a brewing scientist, to understand the management of a craft brewery, some technical constraints and certain other issues concerning craft brewing. The results are presented in accordance with the objectives of the study. Initially, the findings of the two case studies are presented separately, starting with a brief summary of each case study. Thereafter, the results and findings are organised according to the research objectives. Tables and diagrams have been used to summarise the findings.

4.2 Data Collection and Analysis

The step by step process used to gather data is shown in figure 3.6 in chapter 3. The semi-structured interviews were conducted with three brewing industry experts. The brew masters from brewery A and B were interviewed as the experts. The third expert was a local certified brewing consultant. A digital voice recorder was used to record the responses of the participants and these recordings were later transcribed. The brewing consultant who was familiar with both of the breweries also agreed to provide a written response to the interview guide questions. This is appended as Appendix C. The transcribed qualitative interview data from the interviews were then reduced using NVivo software as described in 3.11.1. The stages used in this process, as suggested by O'Neill (2013), are described in table 3.3 in Chapter Three.

Stage 1 Descriptive

The first stage involved entering the project details and data into NVivo. The researcher entered the interview schedules, journal articles and field notes. These were entered into NVivo sources and contained the sub-sections of internals, memos and externals. Figure 4.1 shows the sources section of NVivo and consists of memos, externals and internals.

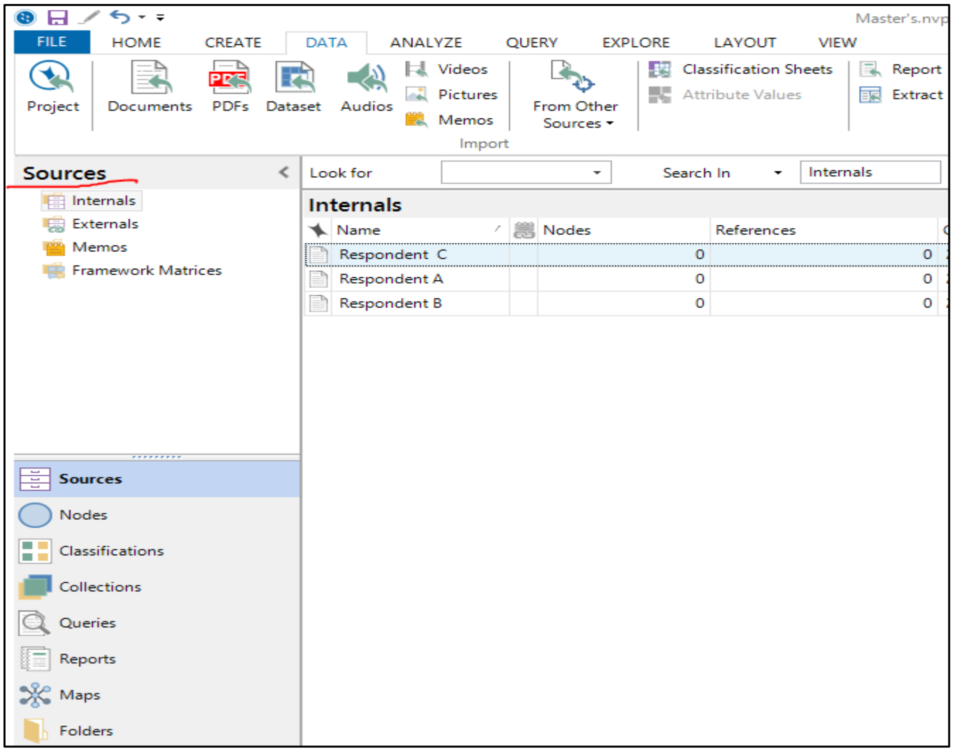


Figure 4. 1 NVivo Sources

Source: *(Researcher's analyses)*

Stage 2 Topics

Stage 2 involved extracting topics from the transcripts and coding. Coding in NVivo allowed the grouping of related concepts to be organised in containers called nodes. Nodes are the themes or topics from the sources. Figure 4.2 shows an extract of the auto coded nodes.

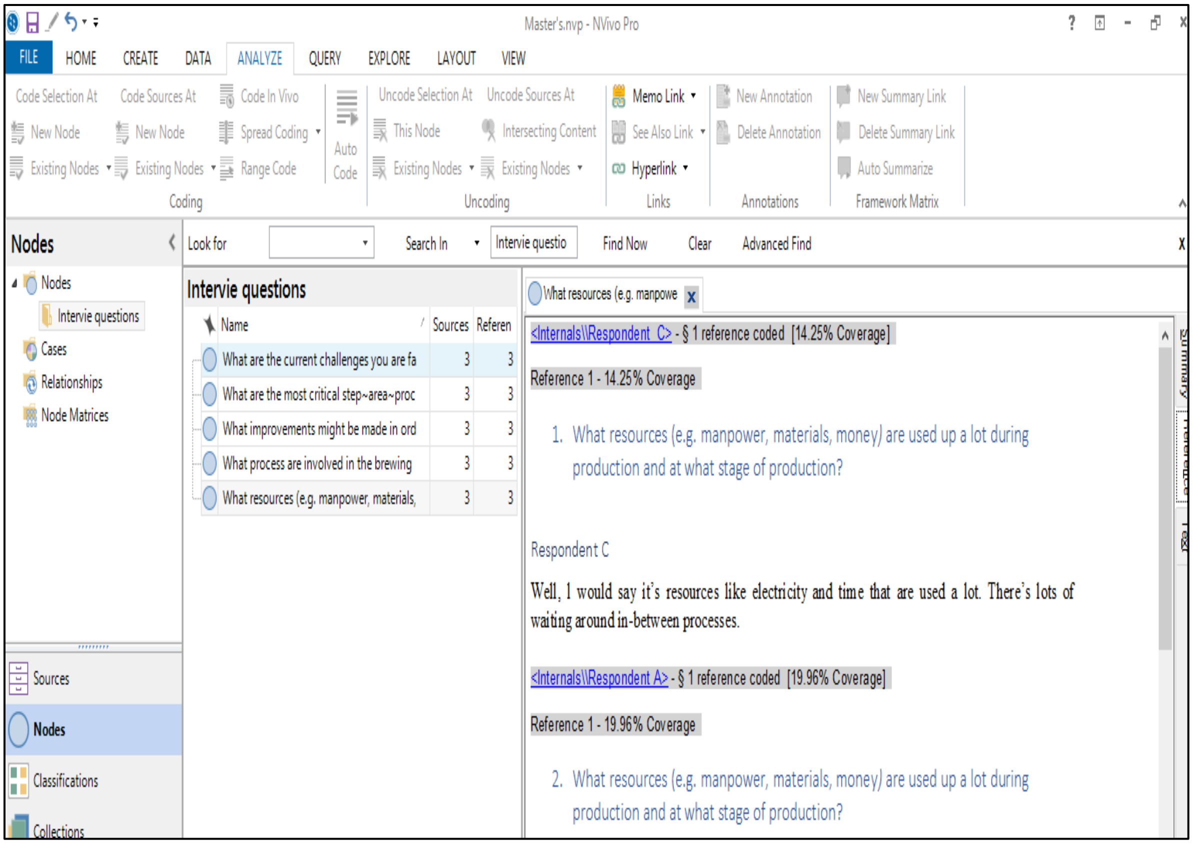


Figure 4. 2 Coding extract

Source: *(Researcher's analyses)*

Stage 3: Analytic

The analytic process allowed the researcher to define concepts and relationships within the data. The analysis which took place involved the merging of the nodes and running queries like word frequencies, creating word clouds, text queries, etc., to determine what words appeared or were used the most. This made it possible to identify the common answers (words) that were provided by the respondents. Figures 4.3 and 4.4 show some extracts from the analyses.

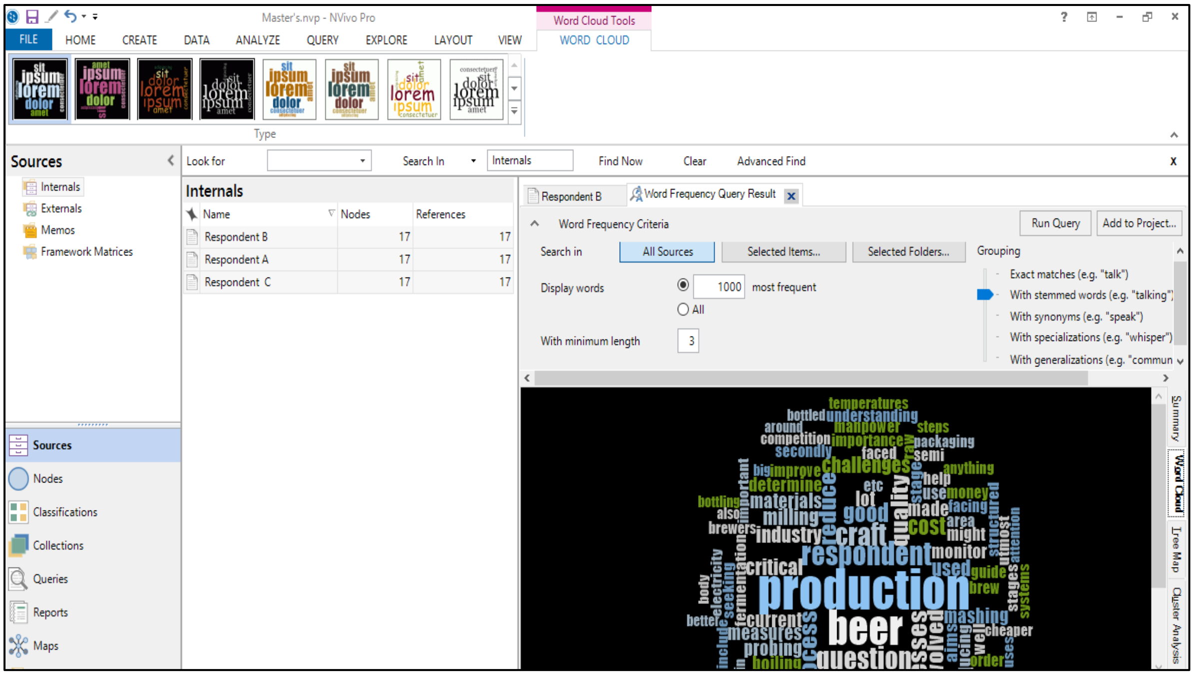


Figure 4. 3 NVivo Analytical extract

Source: (*Researcher's analyses)*

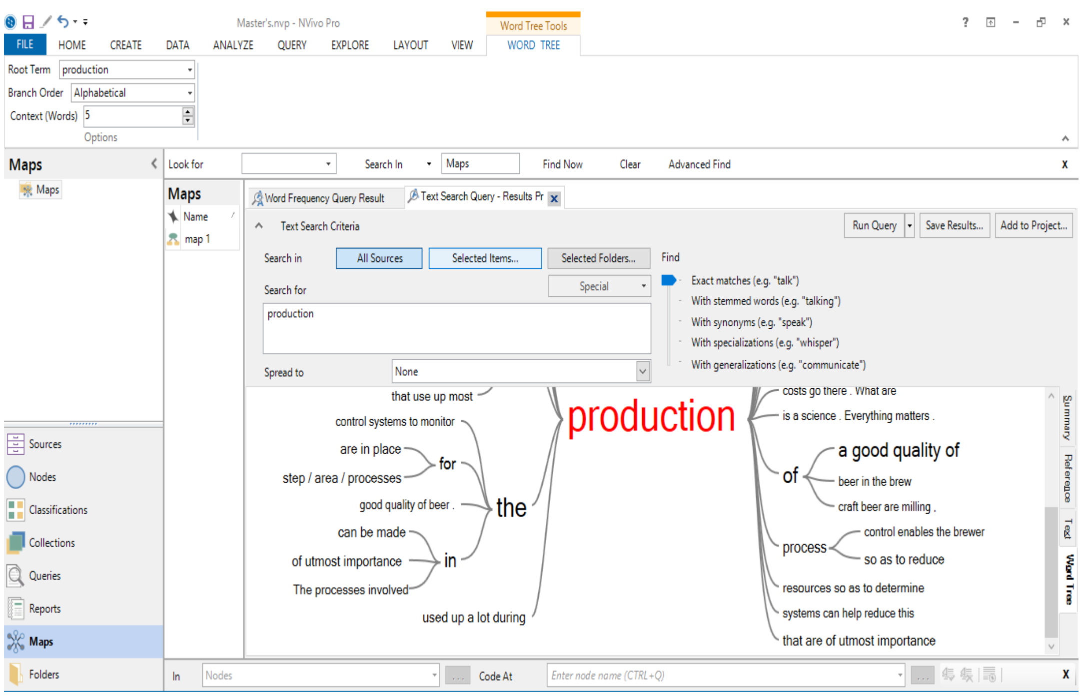


Figure 4. 4 Analytical extract (2)

Source: (*Researcher's analyses)*

Stage 4: Conclusions

The last stage, conclusions, involved verifying the data and developing theories as further discussed in chapter 5. The data was checked for accuracy and developed theories took into account not just these data, but also the data from the observations, records and documentation.

With regards to the observations, the observational schedule was first tested in one brewery, modified and a final version was then constructed. In total, eight observational exercises took place on site, although the first two were pilot visits to each of the breweries. The interview transcripts, observational schedules, records, documents, memos and notes contributed to the results and findings. The semi-structured interview guide and the observation schedule that were used are appended as appendices A and B respectively. Elements in the LAT that scored above 3 were identified. These were identified and are explained in chapter 5.

The following section presents the information that was gathered from the interviews. Findings are presented in the order questions were asked.

4.3 Semi-structured Interview Findings

The findings drawn from the interviews and from information gathered from various documents and archival records is summarised in relation to the 5 semi-structured interview guide questions, as follows:

1. **What process are involved in the brewing of craft beer?**

This question aimed to understand the processes involved in craft brewing to gain an understanding of the brewing process. The generic processes that were mentioned were the processes of milling, mashing, lautering, wort boiling, fermenting, yeast management, bottling and packaging.

2. **What are the most critical step/area/processes for the production of a good quality of beer and what measures are there to monitor or improve these?**

This question probed the critical stages of beer production that are of utmost importance in the production of a good quality of beer. Secondly, it probed what measures are put in place to help ensure the production of good quality beer. The critical processes that were highlighted are summarised in table 4.2.

The brewing experts and the documents examined all stressed the importance of good process monitoring using brewhouse and fermentation control recording sheets. Temperatures, dates, times, ingredients and the specific gravity of the wort and fermenting beer should all be recorded frequently. The importance of good ingredients was highlighted. Meticulous cleaning and effective biosecurity were mentioned. Well trained brewers and brewery workers were considered important. Lastly, having good plant, equipment and measuring instruments was cited as an important measure to monitor and improve the brewing process.

Table 4.2, summarises information on the critical processes or areas in craft brewing and the challenges of the specific areas/processes.

Table 4. 2 Critical processes and areas in beer production

Critical Process/Area	**Challenge**
Milling	To ensure that milling produces the correct grist
Mashing	To ensure mash temperatures are correct, consistent and accurately maintained
Lautering	Is the most error-prone process requiring skill and experience
Post-boil hygiene	To ensure all pipes, vessels and anything that comes into contact with the cooled wort or beer is clean and sterile
Reduce oxygen in beer	To ensure that beer does not come into contact with air
Yeast management	To ensure that yeast is well nourished, healthy, not stressed and not contaminated by other microbes or wild yeast strains
Finished beer handling	To ensure that beer is not contaminated or exposed to heat, light or oxygen

3. **What resources (e.g. manpower, materials, money) are highly consumed during production and at what stage of production?**

This question aimed to evaluate the processes that used up most production resources so as to determine if anything can be done to reduce the usage of these resources. Electricity was mentioned as one of the resources that was used intensively in brewing, mainly for the wort boiling process but also to heat water for mashing and for cleaning purposes. Electricity usage was also high to refrigerate water for wort cooling and to keep the fermenters at the correct temperature, particularly in summertime. Large amounts of water were used for cleaning mash and lauter tuns, kettles, fermenters and also the brewery itself. Large amounts of water were used to clean kegs and rinse bottles in the packaging sections.

The need for manpower was said to vary greatly with peak requirements for milling and mashing, also for bottling with labelling and packaging needing the most manpower. A large amount of money was tied up in ingredients and packaging materials. A big investment in hops was cited, followed by malt. Also, a lot of money was invested in bottles, cardboard boxes and labels. Electricity, water and manpower were the most consumed resources.

4. **What are the current challenges you are facing in the industry?**

This question sought to determine the current challenges faced by the craft beer industry. Challenges mentioned included competition from giants such as AB InBev, a looming water crisis, marketing and distribution challenges and maintaining high quality standards. Electricity supply disruptions were cited as periodic disrupters. Most of the brewing ingredients were imported so when the exchange rate worsened, brewing costs increased. There had been several big increases in the cost of glass bottles too which had a big influence on the profit margins of selling bottled beer rather than kegged beer. Recruiting motivated, competent and trained manpower was seen as a big challenge for craft breweries. Also, it was contended that, due to the rapid increase in the number of craft breweries in South Africa, trained and competent brewery workers were tempted to leave existing jobs and move to new craft breweries where better salaries were offered.

5. **What improvements might be made in order to reduce the cost of producing craft beer?**

This question probed the likelihood of improvements that could be made in the production process so as to reduce the overall cost of production. More and better training programmes would help brewery workers to identify better production methods that potentially might reduce operational costs and improve quality. The certified brewing consultant felt that some of the brewing practices in craft breweries are outdated, inefficient or actually incorrect and can often result in poor quality beer, inconsistent quality beer or a beer where the quality deteriorates rapidly. For example, no quality checks were being conducted. The expert stated that there was scope to introduce better monitoring equipment and production practices.

The results from the semi-structured interviews were used in conjunction with the data from direct observations, participant observations, records and documentation to answer the research questions. The records and documentation provided information about:

- The number of brews in the year
- The type of beer brewed
- Temperature control charts (the temperature control chats were not consistent as some brews had blanks)
- Maintenance schedules
- The quantity of the ingredients
- Individual brewing reports
- Filtration procedures
- Brew day procedures
- Supplier information
- Delivery schedules
- Customer information

4.4 Case Study 1: Brewery A

Brewery A is located in Hilton, KwaZulu-Natal. It is owned by a private proprietor, who hires a part-time retired brewmaster and a full-time assistant brewer to run the brewery. The building operates as a pub and restaurant and was later moderately renovated to accommodate a 10-hectolitre brewery. Four types of beer are produced in the brewery; an ale, a lager, an IPA and a stout. Typically, one batch of 900 litres of beer is brewed each week.

4.4.1 Research Question 1

- ***What assessment tools may be used to assess waste in craft breweries?***

The lean assessment tool sought to assess the extent to which the brewery used lean principles in various areas of the organisation, so as to assess the level of waste in the craft breweries. This data was gathered from direct observations, participant observations, records and documentation. All of this information gathered from the sources mentioned was used to generate the resulted presented in the tables. The results are presented in Tables 4.3 to 4.9 and were recorded on the basis of the variables of Process & Equipment, Manufacturing Planning & Control, Human Resources, Product Design, Supplier Relationships and Customer Relationships improvement areas.

Table 4. 3 Lean Assessment Results: Process & Equipment

To what extent has the brewery adopted or uses the following lean principles?						
	Process & Equipment					
		Not at all	**To a small extent**	**To some extent**	**To a moderate extent**	**To a large extent**
		1	**2**	**3**	**4**	**5**
PE1	Set up reduction		**X**			
PE2	Flow lines		**X**			
PE3	Cellular Manufacturing		**X**			
PE4	Rigorous preventive maintenance		**X**			
PE5	Error- proof equipment		**X**			
PE6	Progressive use of new process technologies		**X**			
PE7	Process capability				**X**	

PE8	Order and cleanliness in the plant			**X**		
PE9	Continuous reduction of cycle time		**X**			

These results are presented in Table 4.3 and indicate that setup reduction, flow lines, rigorous preventive maintenance, error-proof equipment and progressive technologies and continuous reduction of cycle time were principles that had been adopted or used to a small extent. Cellular manufacturing (an approach in which equipment and workstations are arranged to facilitate small lot, continuous flow, by placing all operations that are necessary to produce a component are performed in close proximity) and order and cleanliness in the plant were adopted or used to some extent. Process capability was adopted to a moderate extent.

Table 4. 4 Lean Assessment Results: Manufacturing, Planning and Control

To what extent has the brewery adopted or uses the following lean principles?						
	Manufacturing Planning and Control					
		Not at all	**To a small extent**	**To some extent**	**To a moderate extent**	**To a large extent**
		1	**2**	**3**	**4**	**5**
PPC1	Levelled production		**X**			
PPC2	Synchronised scheduling			**X**		
PPC3	Mixed model scheduling	**X**				
PPC4	Under-capacity scheduling	**X**				
PPC5	Small lot sizing					**X**
PPC6	Visual control of the shop floor		**X**			
PPC7	Overlapped production		**X**			
PPC8	Pull flow control		**X**			

The lean assessment of manufacturing, planning and control is shown in Table 4.4 above. Levelled production, visual controls, overlapped production, and pull flow control lean improvement programmes were adopted to a small extent, whilst synchronized scheduling was used to some extent. Mixed model scheduling and under capacity scheduling were not used at all. Small lot sizing was used to a large extent.

Table 4. 5 Lean Assessment Results: Human Resource

To what extent has the brewery adopted or uses the following lean principles?						
	Human Resource					
		Not at all	**To a small extent**	**To some extent**	**To a moderate extent**	**To a large extent**
		1	**2**	**3**	**4**	**5**
HR1	Multifunctional workers					**X**
HR2	Expansion of autonomy and responsibility				**X**	
HR3	Few levels of management				**X**	
HR4	Worker involvement in continuous quality improvement programmes			**X**		
HR5	Worktime flexibility			**X**		
HR6	Team decision making				**X**	
HR7	Worker training			**X**		
HR8	Innovative performance appraisal and performance related pay systems		**X**			

The results of the lean assessment of the human resource are shown in Table 4.5. Workers at this brewery performed multifunctional tasks to a large extent. Team decision making, few levels of management as well as the expansion of autonomy and responsibility amongst workers was adopted to a moderate extent. Worker involvement in continuous quality improvement programmes, worktime flexibility, and worker training programmes were adopted to some extent, whilst innovative performance appraisal and performance related pay systems were adopted to a small extent.

Table 4. 6 Lean Assessment Results: Product Design

To what extent has the brewery adopted or uses the following lean principles?						
	Product Design					
		Not at all	**To a small extent**	**To some extent**	**To a moderate extent**	**To a large extent**
		1	**2**	**3**	**4**	**5**
PD1	Parts standardization				**X**	
PD2	Product modularisation		**X**			
PD3	Mushroom concept		**X**			
PD4	Design for manufacturability			**X**		
PD5	Phase overlapping		**X**			
PD6	Multifunctional design teams			**X**		

Lean assessment of product design is shown in Table 4.6. The principle of parts standardisation was adopted to a moderate extent. Product modularisation, mushroom concept, and phase overlapping were adopted to a small extent. Design for manufacturability and multifunctional design teams' principles were implemented to some extent.

Table 4. 7 Lean Assessment Results: Supplier Relationships

To what extent has the brewery adopted or uses the following lean principles?						
	Supplier Relationships					
		Not at all	**To a small extent**	**To some extent**	**To a moderate extent**	**To a large extent**
		1	**2**	**3**	**4**	**5**
SR1	JIT deliveries		**X**			
SR2	Open orders		**X**			
SR3	Quality at the source		**X**			
SR4	Early information exchange on production plans		**X**			
SR5	Supplier involvement in quality improvement programmes		**X**			
SR6	Reduction of number of sources and distances			**X**		
SR7	Long-term contracts					**X**
SR8	Total cost supplier evaluation	**X**				
SR9	Supplier involvement in product design and development		**X**			

Table 4.7 shows how long-term contracts were used to a large extent. JIT deliveries, open orders, quality at source, early information exchange on production plans, supplier involvement in quality improvement programmes, long-term contracts, supplier involvement in product design and development were all adopted to some extent, whilst the reduction in number of sources and distances principle was adopted to some extent. Total cost supplier evaluation was not adopted at all.

Table 4. 8 Lean Assessment Results: Customer Relationships

To what extent has the brewery adopted or uses the following lean principles?						
	Customer Relationships					
		Not at all	**To a small extent**	**To some extent**	**To a moderate extent**	**To a large extent**
		1	**2**	**3**	**4**	**5**
CR1	Reliable and prompt deliveries					**X**
CR2	Commercial actions to stabilise demand		**X**			
CR3	Capability and competence of sales network			**X**		
CR4	Early information on customer needs		**X**			
CR5	Flexibility on meeting customer requirements		**X**			
CR6	Service-enhanced product	**X**				
CR7	Customer involvement in product design	**X**				
CR8	Customer involvement in quality programmes	**X**				

With regards to customer relationships, as shown in Table 4.8, the concept of reliable and prompt deliveries was adopted to a large extent whilst the sales network was considered to be capable and competent to some extent. Commercial actions to stabilise demand, early information on customer needs and flexibility on meeting customer requirements principles were only adopted to a small extent. Service-enhanced products, customer involvement in product design as well as customer involvement in quality programmes were not adopted at all.

The lean assessment tool sought to assess the extent to which the brewery evidenced lean principles in the various areas of the organisation, as this would provide an indication of the waste that may have been occurring in the craft brewery. Table 4.9 lists the lean principles applied in Brewery A to a moderate or large extent:

Table 4. 9 Summary of lean principles applied in Brewery A

Area	Lean principles applied to a moderate or large extent
Process & Equipment	Process capability
Manufacturing Planning & Control	Small lot sizing
Human Resources	Multifunctional workers, expansion of autonomy and responsibility, few levels of management, team decision making
Product Design	Part standardisation
Supplier Relationships	Long term contracts
Customer Relationships	Reliable and prompt deliveries

4.4.2 Research Question 2

- ***What wastes occur in craft breweries?***

The second research objective was to identify the wastes that may occur at the craft breweries.

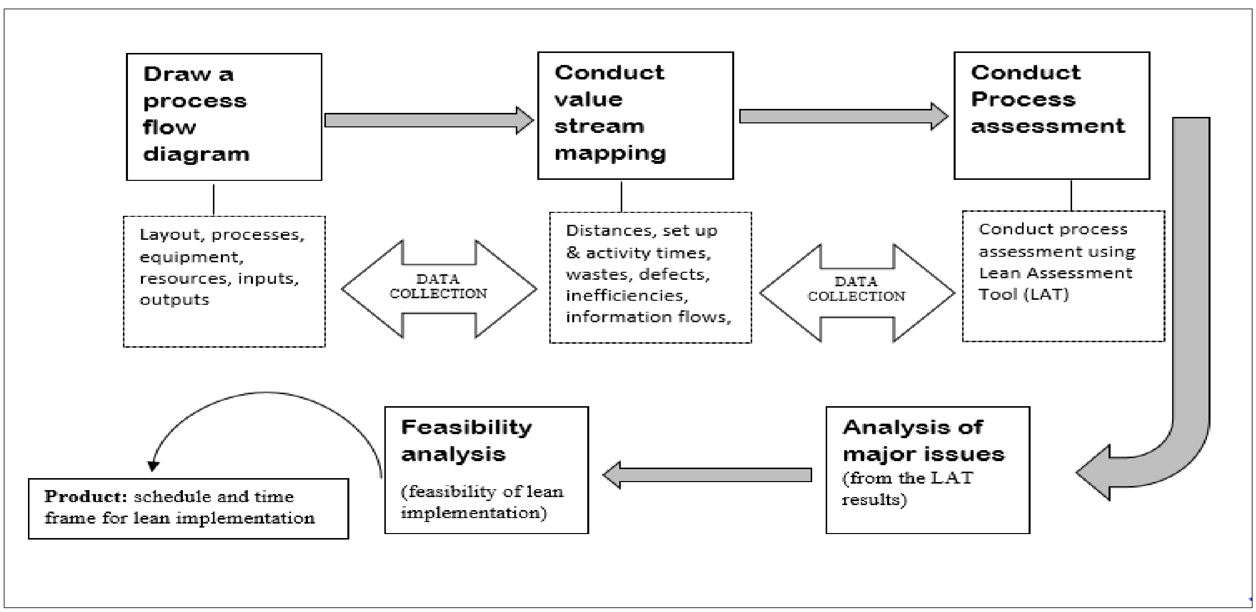


Figure 4. 5 Data Collection Procedure

Source*: (Compiled by the Researcher*)

In order to do this, process flow and value stream mapping exercises were conducted (Figure 4.6) and the sources of waste and inefficiencies were identified in accordance with the discussion in chapter two. The information which was used to answer this research question came from direct observations, participant observations, archival records and documentation.

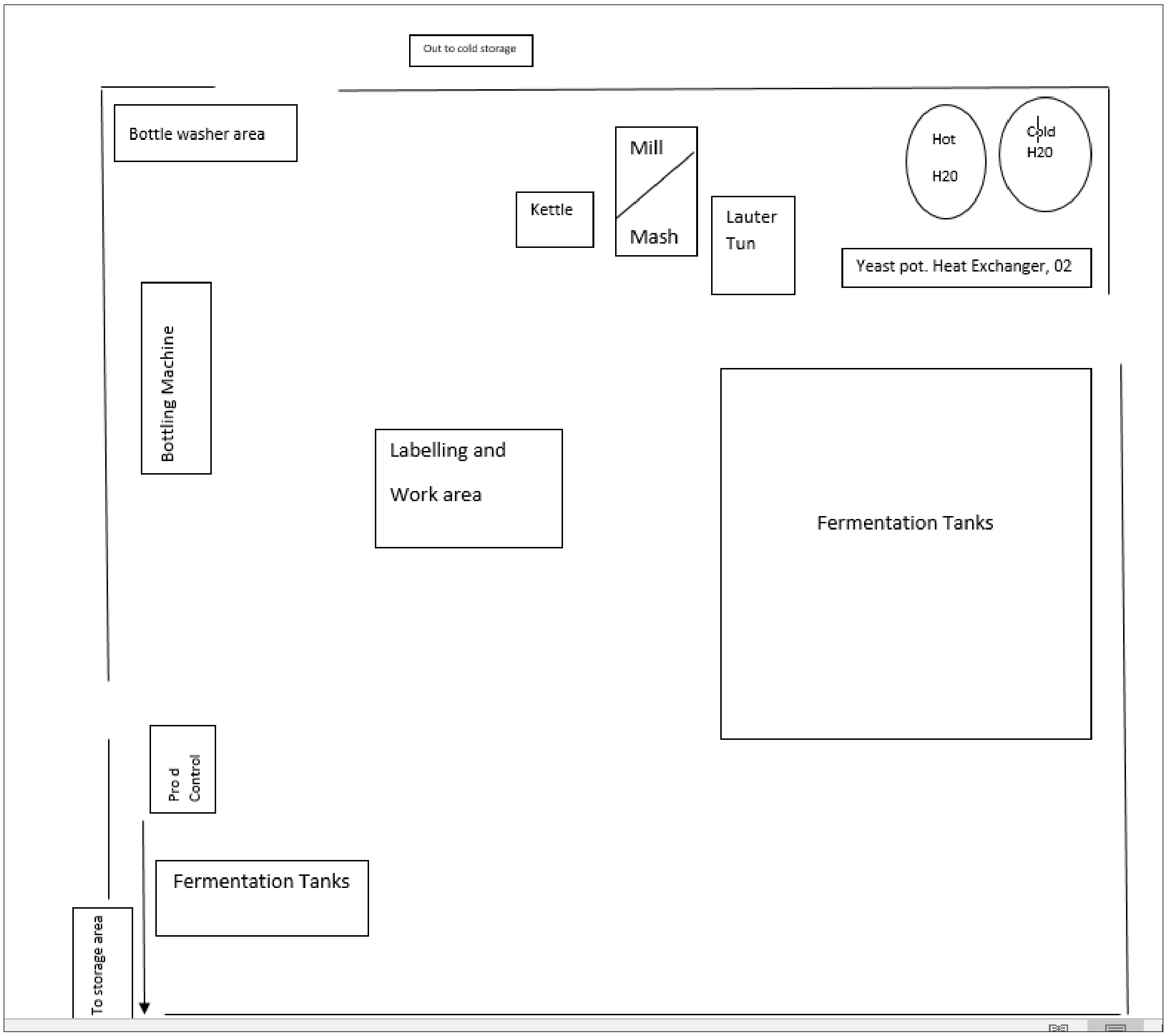


Figure 4. 6 Layout of Brewery A

Source*: (Compiled by the Researcher*)

The ingredients needed for brewing are taken from the storeroom to the milling area. Milling, mashing, lautering and the wort boiling processes take place and then the beer is transferred to the fermentation tanks. The bottles are washed and labelled in the 'bottling and packaging' area and the tools and equipment needed for this, e.g. labelling stickers, sealing-tape, etc, are taken from the tools area. The beer is then bottled or put into kegs and taken to the cold-room for storage.

Value Stream Map

The value stream mapping exercise was conducted using the steps discussed in Chapter Two. These include: identify the product family, bound the process and identify the process steps, gather material and information flows, collect process data, draw current state map and identify wastes (Rother & Shook, 2009).

Product family

The brewery makes one product, beer. Although the flavours are different, the beer made passes through the same process and therefore the product being mapped is beer.

Process bounds and process steps

The starting point of the value stream was the main suppliers and the end point the 1st tier customers. The main suppliers included those who provide water, malt, hops, yeast, bottles, bottle caps, boxes and suppliers who provided services that include refrigeration. The process steps included milling, mashing, lautering, boiling, fermentation, bottling and packing.

Information Flows

Information flows from production are recorded mainly manually and some electronically. The electronic information comes from the central control system, which is used to record and monitor the production process. Other information is manually recorded and communicated.

Process data

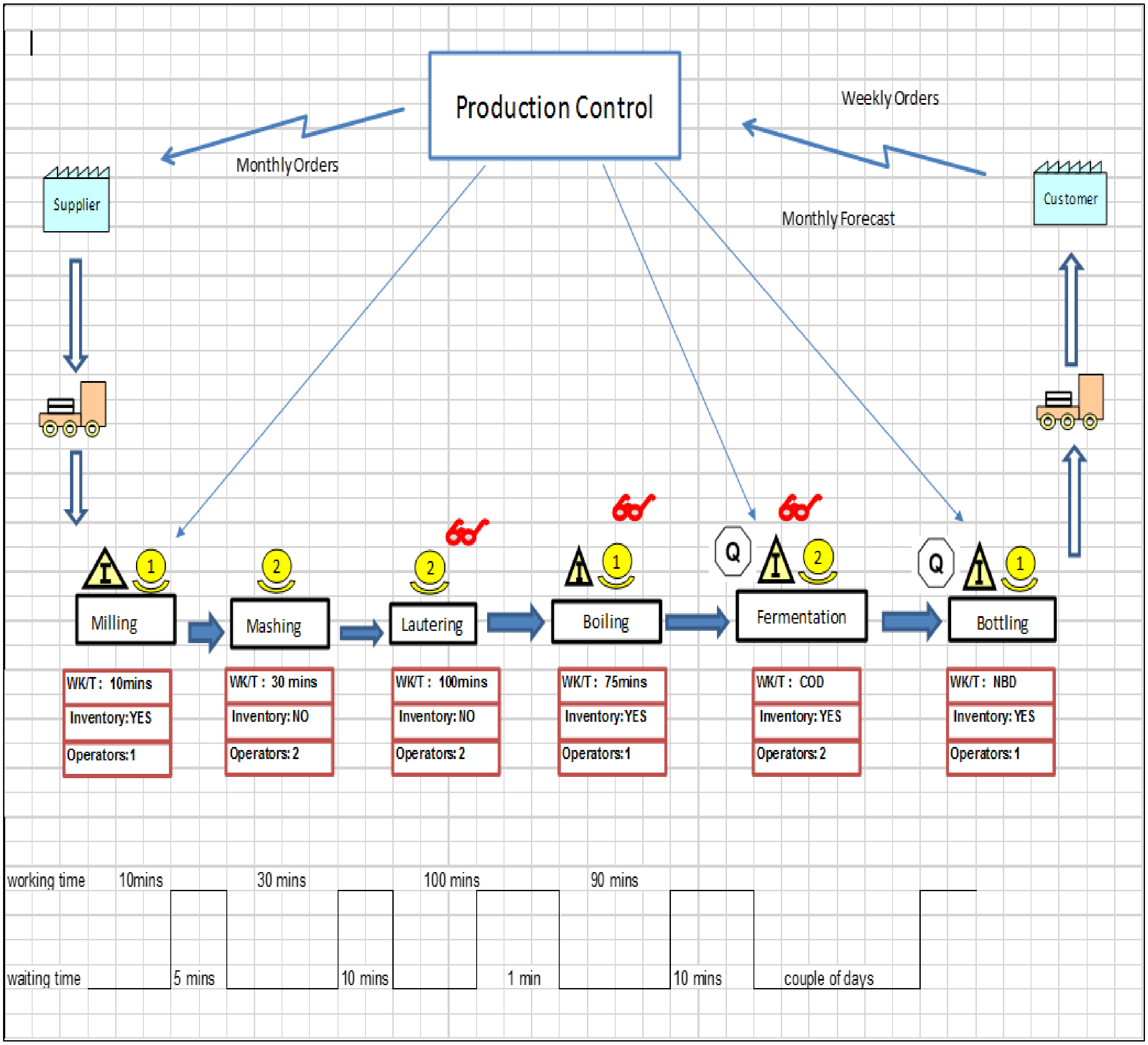
The collected process data is summarised in Table 4.10.

Table 4. 10 Process Data for Brewery A

Data Type	Process Steps						
	Pre-fermentation steps	Milling	Mashing	Lautering	Boiling	Fermentation (1st stage)	Bottling (from F. Tank)
Setup time	30mins						
Working time	-	10mins	90mins	100mins	75mins	120mins	Non-brewing days
Waiting time	-	5mins					
Distances	-	<1m> <1m> <1m> <5m> <6m>					
Batch size/ Av. frequency	900liters/week						
Bottle size	500ml						
Bottling times	Non-brewing days are bottling days						

Drawing current state map

The value stream map for brewery A is depicted in Figure 4.8.



Map Key

						Q		15 sec. Processing Time
Operator	Supplier/ customer	Inventory	Electronic Info flow	Manual Info flow	Go-see schedule	Quality problem area	Shipment	Processing Time

Figure 4. 7 Value Stream Map for Brewery A

Source: (*Compiled by the Researcher)*

Identifying wastes and inefficiencies

Table 4.11 lists the sources of waste and inefficiencies that were observed at craft brewery A.

Table 4. 11 Wastes/ Inefficiencies

• Labelling system faulty	• Sterilisation insufficient
• Cracked bottes	• Broken machinery laying around
• Beer quality problems	• Store room dark, no lights
• Pipes/tubes not standard	• No SOPs for cleaning
• No continuous improvement measures	• Pipes/tubes too long
• Mill dirty	• Too much inventory of the wrong malt
• No facility to prevent leakages	• Bottle washer used as bottle cleaner
• Poor cleaning of plant & equipment	• Broken gauges
• Fermenter taps not sterilised	• Inefficient layout
• Bottled beer lying around	

4.4.3 Research Question 3

- ***Are lean principles appropriate for application in craft breweries and if so, how can craft brewers introduce lean principles in their production processes to improve quality and reduce costs?***

With existing production capabilities, the feasibility of implementing or improving lean principles in brewery A is summarised in table 4.12. The feasibility was determined from observations as well as from records and documentation. The principles that scored 5 and 4 are considered to be the most feasible lean principles that can more easily be introduced or improved to improve quality and reduce cost.

Table 4. 12 Feasibility Assessment Results

1 =very difficult 2 =difficult 3 =neutral 4 = easy 5 = very easy											
HOW FEASIBLE WILL IT BE TO IMPLEMENT OR IMPROVE THE DIFFERENT LEAN PRINCIPLES?											
Process & Equipment		Manufacturing planning and control		Human Resource		Product Design		Supplier relationships		Customer Relationships	
PE1	3	**PPC1**	3	**HR1**	5	**PD1**	4	**SR1**	3	**CR1**	4
PE2	3	**PPC2**	2	**HR2**	4	**PD2**	2	**SR2**	3	**CR2**	3
PE3	2	**PPC3**	2	**HR3**	5	**PD3**	2	**SR3**	4	**CR3**	3
PE4	5	**PPC4**	2	**HR4**	4	**PD4**	2	**SR4**	1	**CR4**	3
PE5	3	**PPC5**	4	**HR5**	2	**PD5**	2	**SR5**	2	**CR5**	3
PE6	2	**PPC6**	5	**HR6**	4	**PD6**	2	**SR6**	2	**CR6**	2
PE7	3	**PPC7**	3	**HR7**	2			**SR7**	5	**CR7**	2
PE8	5	**PPC8**	2	**HR8**	2			**SR8**	**2**	**CR8**	1
PE9	4							**SR9**	**2**		

<u>Process & Equipment</u>

With regards to improving or making changes to the lean principles associated with process and equipment, the lean principles that can most easily be introduced include rigorous preventative maintenance (PE4), order and cleanliness in the plant (PE8) and a continuous reduction of cycle time (PE9)

<u>Manufacturing Planning & Control</u>

Lean principles influencing the manufacturing, planning and control area that can be easily introduced or improved include small lot sizing (PPC5) and visual control of the shop floor (PPC6).

Human Resources

With regard to the Human Resources, multifunctional workers (HR1), expansion of autonomy and responsibility (HR2), few levels of management (HR3), worker involvement in continuous quality improvement programmes (HR4) and team decision making (HR6) are lean principles that can be easily introduced or improved upon in craft brewery A.

Product Design

For product design, parts standardisation (PD1), will be the most feasible lean principle to implement or improve.

Supplier Relationships

Quality at source (SR3) and long-term contracts (SR7) are the lean principles which could be introduced or improved on in craft brewery A.

Customer Relationships

Under the current production capabilities, reliable and prompt deliveries (CR1) as well as the capability & competence of sales the network (CR3) are the most feasible lean principles that can be introduced or improved upon in the brewery.

Further discussion of the feasibility of introducing or improving upon these lean principles in the brewing process will be provided in the chapter.

4.5 Case Study 2: Brewery B

Brewery B is located in Nottingham Road, KwaZulu-Natal and is privately owned. The proprietor hires one brew-master, an assistant brewer and five other staff members in the brewery. Brewery B was designed specifically for craft brewing of 10 hectolitre batches. Eight types of house brand beers are brewed: The brewing takes place every weekday, sometimes twice a day, with an average of 22 hectolitres brewed each week.

4.5.1 Research Question 1

- ***What assessment tools may be used to assess waste in craft breweries?***

The existence and extent of lean principles in various areas of the organisation were assessed, so as to assess the extent of waste in the craft brewery. The results were recorded, with 1 = not at all, 2 = to a small extent, 3 = to some extent, 4 = to a moderate extent and 5 = to a large extent. The results are presented in Tables 4.13 to 4.18, and categorised in terms of Process & Equipment, Manufacturing, Planning & Control, Human Resources, Product Design, Supplier Relationships and Customer Relationships improvement areas.

Table 4. 13 Lean Assessment Results: Process & Equipment

To what extent has the brewery adopted or uses the following lean principles?						
	Process & Equipment					
		Not at all	**To a small extent**	**To some extent**	**To a moderate extent**	**To a large extent**
		1	**2**	**3**	**4**	**5**
PE1	Set up time reduction				**X**	
PE2	Flow lines		**X**			
PE3	Cellular Manufacturing			**X**		
PE4	Rigorous preventive maintenance				**X**	
PE5	Error – proof equipment				**X**	
PE6	Progressive use of new process technologies			**X**		
PE7	Process capability		**X**			
PE8	Order and cleanliness in the plant				**X**	
PE9	Continuous reduction of cycle time		**X**			

Setup time reduction, error proof equipment and rigorous preventive maintenance were adopted to a moderate extent. Cellular manufacturing, progressive use of new process technologies and order and cleanliness in the plant were principles adopted to some extent. Flow lines, process capability and continuous reduction of cycle time were only seen to a small extent.

Table 4. 14 Lean Assessment Results: Manufacturing Planning and Control

To what extent has the brewery adopted or uses the following lean principles?						
	Manufacturing Planning and Control					
		Not at all	**To a small extent**	**To some extent**	**To a moderate extent**	**To a large extent**
		1	**2**	**3**	**4**	**5**
PPC1	Levelled production		**X**			
PPC2	Synchronised scheduling		**X**			
PPC3	Mixed model scheduling			**X**		
PPC4	Under-capacity scheduling			**X**		
PPC5	Small lot sizing				**X**	
PPC6	Visual control of the shop floor				**X**	
PPC7	Overlapped production			**X**		
PPC8	Pull flow control					**X**

In Table 4.14, levelled production and synchronised scheduling can be seen to have been implemented to a small extent. Mixed model scheduling, under capacity scheduling and overlapped production concepts were adopted to a moderate extent. Small lot sizing and visual control of the shop floor were adopted to a moderate extent, whilst the pull flow control lean improvement programme was adopted to a large extent.

Table 4. 15 Lean Assessment Results: Human Resource

To what extent has the brewery adopted or uses the following lean principles?						
	Human Resource					
		Not at all	**To a small extent**	**To some extent**	**To a moderate extent**	**To a large extent**
		1	**2**	**3**	**4**	**5**
HR1	Multifunctional workers			**X**		
HR2	Expansion of autonomy and responsibility			**X**		
HR3	Few levels of management					**X**
HR4	Worker involvement in continuous quality improvement programmes			**X**		
HR5	Worktime flexibility		**X**			
HR6	Team decision making				**X**	
HR7	Worker training			**X**		
HR8	Innovative performance appraisal and performance related pay systems	**X**				

In table 4.15 it can be seen that the principle of a few levels of management was adopted to a large extent, whilst the team decision principle was adopted to a moderate extent. Multifunctional workers, expansion of autonomy and responsibility, worker involvement and worker training were adopted to some extent. Worktime flexibility was adopted to a small extent and innovative performance appraisal and performance related pay systems was not adopted at all.

Table 4. 16 Lean Assessment Results: Product Design

To what extent has the brewery adopted or uses the following lean principles?						
	Product Design					
		Not at all	**To a small extent**	**To some extent**	**To a moderate extent**	**To a large extent**
		1	**2**	**3**	**4**	**5**
PD1	Parts standardization			**X**		
PD2	Product modularisation		**X**			
PD3	Mushroom concept			**X**		
PD4	Design for manufacturability			**X**		
PD5	Phase overlapping			**X**		
PD6	Multifunctional design teams		**X**			

In table 4.16 it can be seen how parts standardisation, the mushroom concept, design for manufacturability and phase overlapping were adopted to some extent. Product modularisation and multifunctional design teams were adopted to a small extent.

Table 4. 17 Lean Assessment Results: Supplier Relationships

To what extent has the brewery adopted or uses the following lean principles?						
	Supplier Relationships					
		Not at all	**To a small extent**	**To some extent**	**To a moderate extent**	**To a large extent**
		1	**2**	**3**	**4**	**5**
SR1	JIT deliveries			**X**		
SR2	Open orders		**X**			
SR3	Quality at the source			**X**		
SR4	Early information exchange on production plans	**X**				
SR5	Supplier involvement in quality improvement programmes	**X**				
SR6	Reduction of number of sources and distances				**X**	
SR7	Long-term contracts				**X**	
SR8	Total cost supplier evaluation	**X**				
SR9	Supplier involvement in product design and development	**X**				

Table 4.17 shows how the reduction in the number of sources and distances and the long-term contracts principles were applied to a moderate extent. JIT deliveries and quality at source were adopted to some extent. Whilst open orders were adopted to a small extent. Early information exchange on production plans, supplier involvement in quality improvement programmes, total cost supplier evaluation and supplier involvement in product design and development were not adopted at all.

Table 4. 18 Lean Assessment Results: Customer Relationships

To what extent has the brewery adopted or uses the following lean principles?						
	Customer Relationships					
		Not at all	**To a small extent**	**To some extent**	**To a moderate extent**	**To a large extent**
		1	**2**	**3**	**4**	**5**
CR1	Reliable and prompt deliveries					**X**
CR2	Commercial actions to stabilise demand			**X**		
CR3	Capability and competence of sales network			**X**		
CR4	Early information on customer needs			**X**		
CR5	Flexibility on meeting customer requirements				**X**	
CR6	Service-enhanced product		**X**			
CR7	Customer involvement in product design	**X**				
CR8	Customer involvement in quality programmes	**X**				

In table 4.18 it is shown how the concept of reliable and prompt deliveries was adopted to a large extent whilst flexibility on meeting customer demands was seen to a moderate extent. The commercial actions to stabilise demand, the capability and competence of the sales network and early information on customer needs were seen only to some extent. Service-enhanced products, customer involvement in product design and customer involvement in quality programmes were seen to a small extent or not adopted at all.

The lean assessment tool sought to assess the extent to which the brewery evidenced lean principles in the various areas of the organisation, as this would provide an indication of the waste that may have been occurring in the craft brewery. Table 4.19 lists the lean principles applied in Brewery B to a moderate or large extent:

Table 4. 19 Summary of lean principles applied in Brewery B

Area	Lean principles applied to a moderate or large extent
Process & Equipment	Set up reduction, 'error-proof equipment, order and cleanliness in the plant
Manufacturing Planning & Control	Small lot sizing, visual control of the shop floor area, pull flow control
Human Resources	Few levels of management
Product Design	Mushroom concept
Supplier Relationships	Reduction of number of sources and distances, long term contracts
Customer Relationships	Reliable and prompt deliveries, commercial actions to stabilise demand, capability and competence of sales network, flexibility on meeting customer requirements

4.5.2 Research Question 2

- ***What wastes occur in craft breweries?***

The second research objective was to identify the sources of waste in craft breweries. In order to do this, the process flow and the value stream mapping exercises were conducted and the sources of waste and inefficiencies were identified.

Process Flow

The process flow shows the layout of the brewery and describes the sequence followed as illustrated in figure 4.9.

The malt is milled the day before production. It is milled and left next to the mash tun. The following morning, the brewing begins with mashing and is then followed by lautering then boiling. Thereafter, beer is sent to an empty fermentation tank, where it is left for the yeast to begin activity. During brewing, the staff who are not involved, bottle, can and package the beer that has finished fermenting, conditioning and has been filtered to improve clarity. The beer is then stored in the cold-room, ready to be sent to customers.

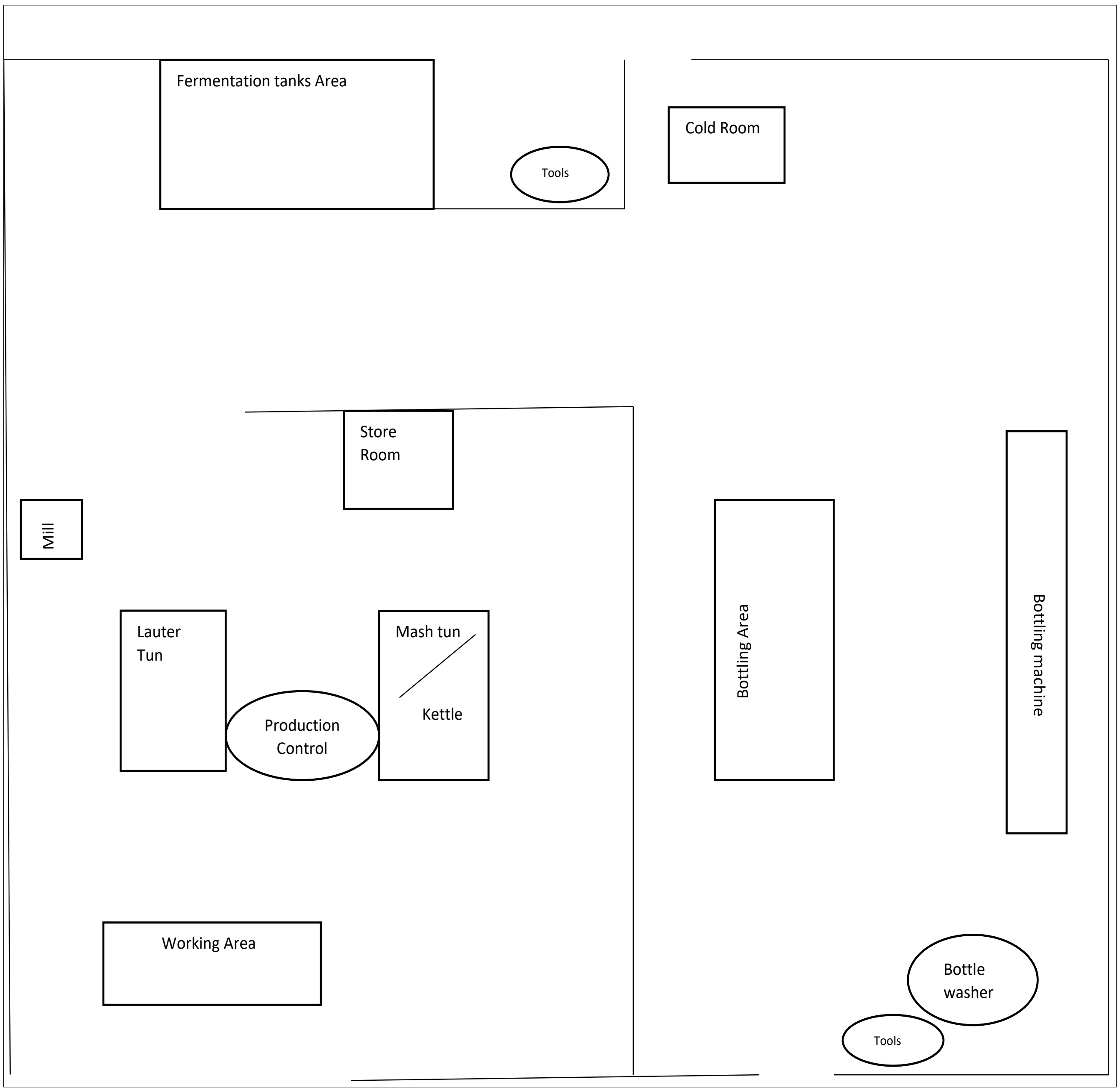


Figure 4. 8 Process Flow of Brewery B

Source: *(Compiled by the Researcher)*

Value Stream Map

The value stream mapping exercise was conducted using the steps discussed in chapter 2. These include: identifying product family, bounding the process and identifying the process steps, gathering material and information flows, collecting process data, drawing current state map and identifying wastes (Rother & Shook, 2009).

<u>Product family</u>

The brewery makes one product, beer. Although the flavours are different, the beer made passes through the same process and therefore the product being mapped is beer.

<u>Bounding the process and Process steps identification</u>

The starting point of this value stream was the main suppliers and the end point the 1^{st} tier customers. The main suppliers included those who provide water, malt, yeast, hops, bottles, cans, bottle caps, boxes and suppliers who provided services that include refrigeration. The process steps included milling, mashing, lautering, boiling, fermentation, bottling and packing.

<u>Information Flows</u>

Information flows from the production control manually and electronically.

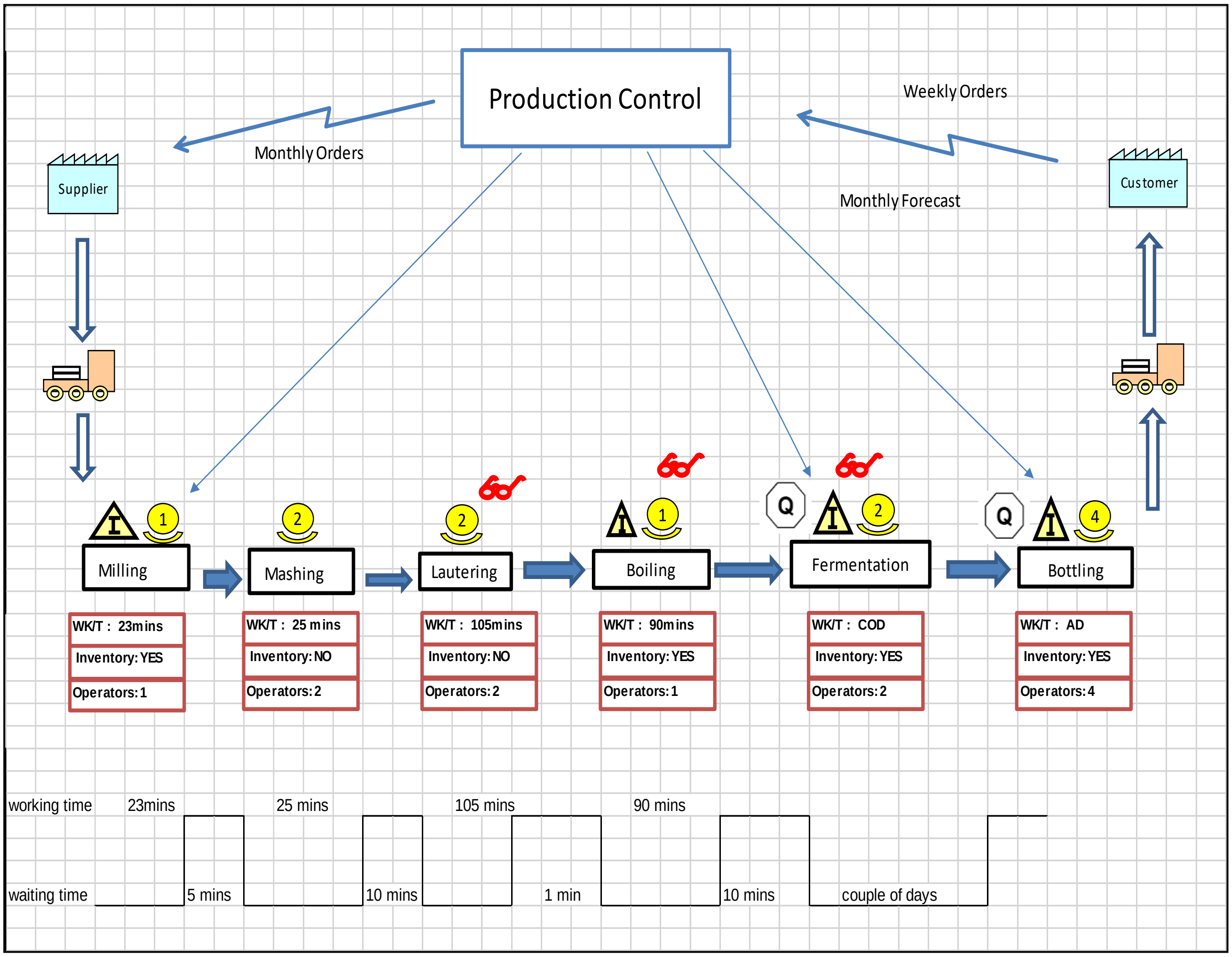
<u>Process data</u>

The process data collected is presented in Table 4.20.

Table 4.20 Process Data for Brewery B

Data Type	Process Steps						
	Pre-fermentation	Milling	Mashing	Lautering	Boiling	Fermentation (1^{st} stage)	Bottling (from F. Tank)
Setup time	6 mins	(prev day)	2 mins	5 mins	8 mins	10mins	
Working time	23 mins	(prev day)	25 mins	105 mins	75 mins		
Waiting time	-	(prev day)	15 mins				
Distances		<4 m> <1.8m> <1.3m> <3.9m> <13.7m>					
Batch size	2 x 1000 = 2000liters/week						
Bottle size	500ml bottles and cans 330ml						
Bottling times	Every brew-day						

A current state value stream map for brewery B is depicted in figure 4.10.



Map Key

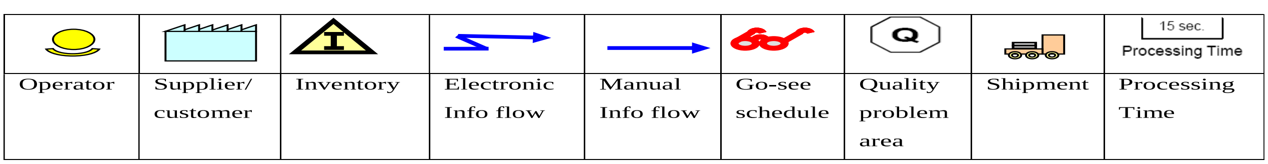


Figure 4. 9 Value Stream Map of Brewery B

Source: *(Compiled by the Researcher)*

Identifying wastes and inefficiencies

Table 4.21 lists the sources of waste and inefficiencies that were observed at the craft brewery.

Table 4. 21 Wastes and Inefficiencies observed at Brewery B

• Problem with lauter turn, leading to left over beer in the tun thrown away	• Cracked bottles lying around
• Bottling machine only takes up to 8 bottles	• Untidy work area
• Flooring unstable in the brewing area	• Tripping of electricity flow during the production process
• Overtime required to finish brewing	

4.5.3 Research Question 3

- ***Are lean principles appropriate for application in craft breweries and if so, how can craft brewers introduce lean principles in their production processes to improve quality and reduce costs?***

Table 4.22 indicates the feasibility of implementing or improving lean principles. The elements which scored 4 and 5 provide an initial set of lean principles that can be easily introduced. Chapter 5 provides a discussion of how lean principles can be introduced in a craft brewery to improve quality and reduce costs.

Table 4. 22 Feasibility Assessment Results

1 = very difficult, 2 = difficult, 3 = neutral, 4 = easy, 5 = very easy											
HOW FEASIBLE WILL IT BE TO IMPLEMENT OR IMPROVE THE DIFFERENT LEAN PRINCIPLES?											
Process & Equipment		Manufacturing planning and control		Human Resource		Product Design		Supplier relationships		Customer Relationships	
PE1	3	**PPC1**	2	**HR1**	4	**PD1**	3	**SR1**	3	**CR1**	4
PE2	3	**PPC2**	1	**HR2**	3	**PD2**	2	**SR2**	2	**CR2**	4
PE3	2	**PPC3**	2	**HR3**	4	**PD3**	4	**SR3**	3	**CR3**	4
PE4	4	**PPC4**	2	**HR4**	2	**PD4**	2	**SR4**	4	**CR4**	4
PE5	2	**PPC5**	4	**HR5**	1	**PD5**	2	**SR5**	3	**CR5**	3
PE6	3	**PPC6**	2	**HR6**	2	**PE6**	2	**SR6**	3	**CR6**	2
PE7	3	**PPC7**	2	**HR7**	4			**SR7**	5	**CR7**	4
PE8	5	**PPC8**	3	**HR8**	1			**SR8**	3	**CR8**	2
PE9	5										

Process & Equipment

With regards to improving or making changes to the lean concepts in process and equipment area, rigorous preventative maintenance (PE4), order and cleanliness in the plant (PE8) and continuous reduction of cycle time (PE9) can be introduced reasonably easily in the brewery.

Manufacturing Planning & Control

In the manufacturing planning and control area, the lean concept which can be easily introduced or improved with the current production capabilities is small lot sizing (PPC5).

Human Resource

Multifunctional workers (HR1), few levels of management (HR3) as well as worker training (HR7) are the lean concepts which can be introduced or improved.

Product Design

The current production capabilities of brewery B allow for the introduction or improvement of the mushroom concept (PD3).

Supplier Relationships

The lean concepts which relate to early information exchange of production plans (SR4) as well as long term contracts (SR7) concepts can easily be introduced or improved.

Customer Relationships

Reliable and prompt deliveries (CR1), commercial actions to stabilise demand (CR2), capability and competence of sales network (CR3), early information on customer needs (CR4) as well as customer involvement in product design (CR7) can be easily introduced or improved in the brewery.

Chapter Five provides a description of how these lean concepts can be introduced and implemented in the production process.

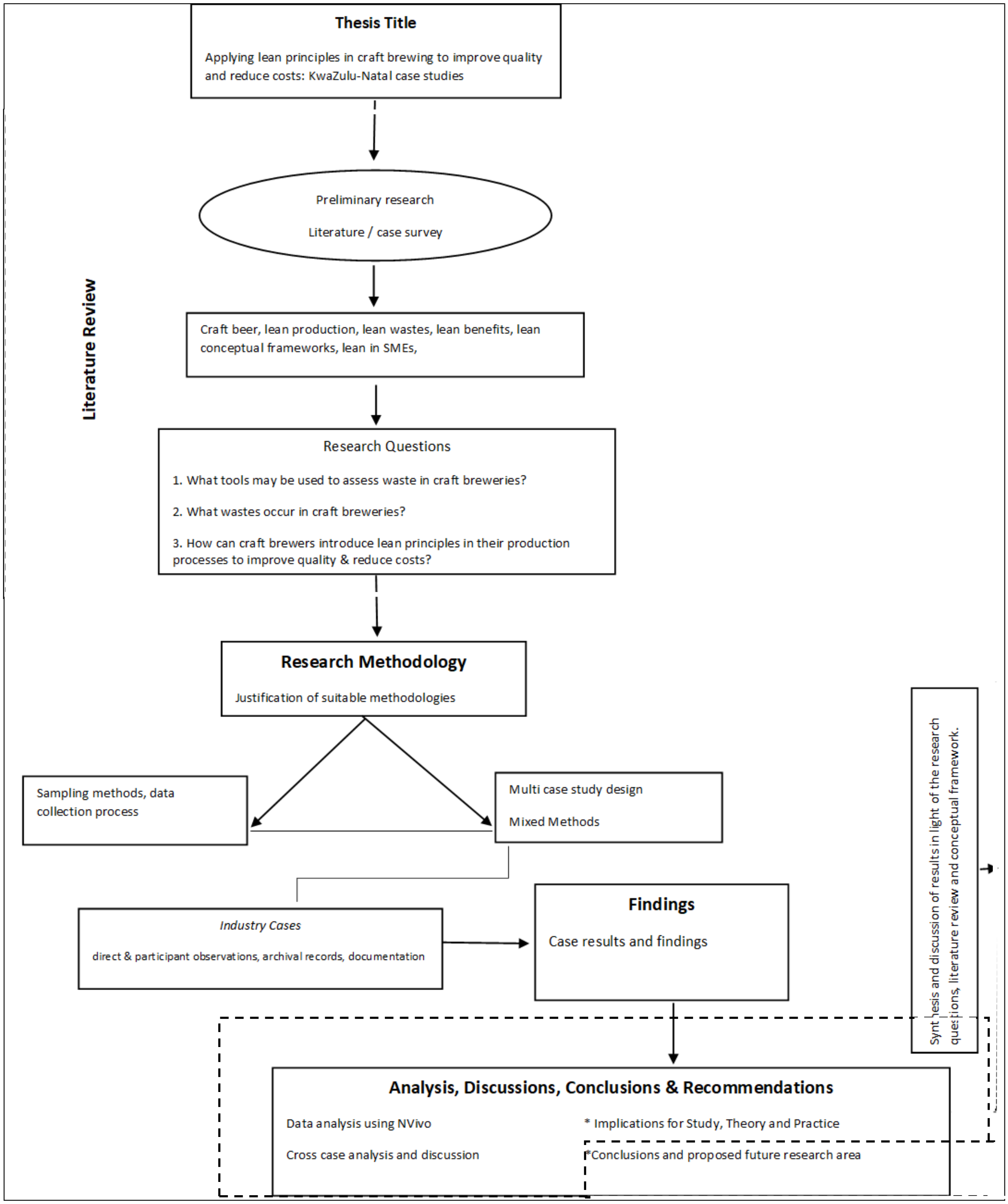
4.6 Chapter Summary

The questions which the study sought to answer were:

1. What tools may be used to assess waste in craft breweries?
2. What wastes occur in craft breweries?
3. Are lean principles appropriate for application in craft breweries and if so, how can craft brewers introduce lean principles in their production processes to improve quality and reduce costs?

To answer these research questions, multi-case studies were conducted at two breweries and expert interviews were carried out. The data was analysed and has been presented in this chapter. To ascertain what tools may be used to assess waste, a process assessment of the brewery was conducted. The various types of tools were identified and a list of the wastes as well as inefficiencies which occurred or were observed at the brewery were also presented. The principles which were applicable to craft brewing and the principles that could be introduced or improved with the current production processes of the breweries were presented.

Chapter Five discusses and describes how the lean concept can be introduced in craft brewing. Also, it further discusses the results presented in this chapter in order to compare the different breweries and to suggest how these differences might contribute to the potential for lean production. In addition, it provides the implications of these results and findings for this this research, for theory and for practice.


Thesis Title
Applying lean principles in craft brewing to improve quality and reduce costs: KwaZulu-Natal case studies
Literature Review
Preliminary research
Literature / case survey
Craft beer, lean production, lean wastes, lean benefits, lean conceptual frameworks, lean in SMEs,
Research Questions
1. What tools may be used to assess waste in craft breweries?
2. What wastes occur in craft breweries?
3. How can craft brewers introduce lean principles in their production processes to improve quality & reduce costs?
Research Methodology
Justification of suitable methodologies
Sampling methods, data collection process
Multi case study design
Mixed Methods
Industry Cases
direct & participant observations, archival records, documentation
Findings
Case results and findings
Synthesis and discussion of results in light of the research questions, literature review and conceptual framework.
Analysis, Discussions, Conclusions & Recommendations
Data analysis using NVivo
Cross case analysis and discussion
* Implications for Study, Theory and Practice
*Conclusions and proposed future research area

CHAPTER FIVE: DISCUSSION

5.1 Introduction

The purpose of this study was to identify appropriate assessment tools that may be used to assess waste in craft breweries. Secondly, it was to identify any sources of waste that may occur in craft breweries and lastly, to determine how craft brewers can introduce lean principles in their production processes to improve quality and reduce costs.

Panizzolo et al. (2012) developed an assessment tool to assess how much progress manufacturing firms had made in implementing lean principles and practices. This study tested this assessment tool to determine if it could be used in craft breweries. In the South African craft brewing industry, little to no reference is made to lean production, although brewers may be implementing certain lean principles and practices. In the process of testing this tool in the two case studies, this research also assessed the extent with which the craft breweries had unintentionally applied lean principles and practices and also the scope available for them to apply the other various lean tools.

This chapter explains the results and findings, as presented in Chapter Four that answer the questions posed for this study. Furthermore, the chapter summarises the main themes that are taken from the literature review and connects these to the research questions of this study. Finally, it describes the implications of the results and findings of this research, in theory and in practice.

In Chapter One, the research problem, objectives and justification of the research were provided. Chapters Two through Four can be categorised into the following main aims:

- To gain an understanding of the existing body of knowledge and a better understanding of the research problem
- To develop a method to investigate the problem and to select the tools for the investigation
- To investigate the problem and to present the results and findings.

Chapter Two provided and discussed the lean production methodologies. Research shows that lean production has evolved over the years, from being used in big companies like Toyota, to being implemented in small and medium firms across all industries (Deflorin & Scherrer-Rathje, 2012; Huxley, 2015). The lean principles, practices, tools and techniques that are suggested for and have been implemented by SMEs include value stream mapping, 5Ss, continuous improvements, standard operations, set up time reduction, visual control, multifunctional employees, pull systems, amongst others (Rose, et al., 2011; Matt & Rauch, 2013; Belhadi, et al., 2016).

The implementation of lean methodologies provides benefits such as; improved quality, reduced operational costs, increased production output per person, fewer process wastes, decreased lead times, reduced work in progress, less rework and a reduction in finished goods inventory for all companies across all industries if correctly implemented (Melton, 2005; Anand & Kodali, 2009; Singh, et al., 2010).

Extensive studies on the implementation of lean methodologies and development of frameworks for industries have been carried out, including a few in the brewing industry (e.g. Owuor, 2016; Panwar, Nepal, Jain & Rathore, 2015). However, these frameworks and lean implementation models have not been tested rigorously in the craft brewing industry. Most literature specific to this sector focuses on the growth of the industry, the science of brewing and on marketing rather than on production management. Additionally, the industry specific lean tools and the methodology for introducing lean in craft breweries was not available. This gap identified in the literature review, formed the basis of the research questions for this study which were;

1. What tools may be used to assess waste in craft breweries?
2. What wastes occur in craft breweries?
3. Are lean principles appropriate for application in craft breweries and if so, how can craft brewers introduce lean principles in their production processes to improve quality and reduce costs?

Chapter Three provided a discussion of the research methodology which was used in this study. This exploratory study followed a multi-case design, using a mixed method approach, where data was gathered and analysed using both qualitative and quantitative approaches. The data was gathered using the research instruments of semi-structured interviews, direct observations, participant observation, documentation and archival records. The results and findings were presented and analysed using the SPSS software and NVivo software. The extent of the validity and reliability were discussed, stipulating their importance for case studies. The limitations of this study were provided as well as a discussion of ethical considerations for the study.

Chapter Four presented the findings and results of the research from the case studies.

5.2 Research Question 1

What tools may be used to assess waste in craft breweries?

The main goal of lean production is to reduce waste and inefficiencies that may occur during production (Stevenson, 2012). Lean comprises numerous tools which may be used to reduce or eliminate waste.

The lean assessment tool used in this study was developed by the researcher and based on the work by Panizzolo et al. (2012). The tool sought to describe and measure, i.e. operationalise, the lean production concept in the various areas of the firm. It assessed the extent to which the breweries had implemented lean principles to reduce waste. A 5-point Likert-type scale was used. The minimum score 1, indicated non-usage, and the maximum score of 5 indicated that the lean principle had been implemented to a very large extent. Scores 2, 3 and 4 indicated that the lean principle was observed to a small, to some or to a moderate extent, respectively. The information used to assess the case study breweries was gathered by using research methods of observations; both direct and participant, and from records and documents.

The scores are shown below. For brewery A, the scores are shown with a red (dark) circle, whilst the scores for brewery B are shown in blue (lighter) circles.

TO WHAT EXTENT HAS THE BREWERY ADOPTED OR USES THE FOLLOWING LEAN PRINCIPLES

	Process & Equipment					
		Not at all	**To a small extent**	**To some extent**	**To a moderate extent**	**To a large extent**
PE1	Setup time reduction	**1**	**2**	**3**	**4**	**5**
PE2	Flow lines	**1**	**2**	**3**	**4**	**5**
PE3	Cellular Manufacturing	**1**	**2**	**3**	**4**	**5**
PE4	Rigorous preventive maintenance	**1**	**2**	**3**	**4**	**5**
PE5	Error – proof equipment	**1**	**2**	**3**	**4**	**5**
PE6	Progressive use of new process technologies	**1**	**2**	**3**	**4**	**5**

PE7	Process capability	**1**	**2**	**3**	**4**	**5**
PE8	Order and cleanliness in the plant	**1**	**2**	**3**	**4**	**5**
PE9	Continuous reduction of cycle time	**1**	**2**	**3**	**4**	**5**
	Manufacturing Planning and Control					
PPC1	Levelled production	**1**	**2**	**3**	**4**	**5**
PPC2	Synchronised scheduling	**1**	**2**	**3**	**4**	**5**
PPC3	Mixed model scheduling	**1**	**2**	**3**	**4**	**5**
PPC4	Under-capacity scheduling	**1**	**2**	**3**	**4**	**5**
PPC5	Small lot sizing	**1**	**2**	**3**	**4**	**5**
PPC6	Visual control of the shop floor	**1**	**2**	**3**	**4**	**5**
PPC7	Overlapped production	**1**	**2**	**3**	**4**	**5**
PPC8	Pull flow control	**1**	**2**	**3**	**4**	**5**
	Human Resource					
HR1	Multifunctional workers	**1**	**2**	**3**	**4**	**5**
HR2	Expansion of autonomy and responsibility	**1**	**2**	**3**	**4**	**5**
HR3	Few levels of management	**1**	**2**	**3**	**4**	**5**
HR4	Worker involvement in continuous quality improvement programmes	**1**	**2**	**3**	**4**	**5**
HR5	Worktime flexibility	**1**	**2**	**3**	**4**	**5**
HR6	Team decision making	**1**	**2**	**3**	**4**	**5**
HR7	Worker training	**1**	**2**	**3**	**4**	**5**
HR8	Innovative performance appraisal and performance related pay systems	**1**	**2**	**3**	**4**	**5**
	Product Design					
PD1	Parts standardization	**1**	**2**	**3**	**4**	**5**
PD2	Product modularisation	**1**	**2**	**3**	**4**	**5**
PD3	Mushroom concept	**1**	**2**	**3**	**4**	**5**
PD4	Design for manufacturability	**1**	**2**	**3**	**4**	**5**
PD5	Phase overlapping	**1**	**2**	**3**	**4**	**5**
PD6	Multifunctional design teams	**1**	**2**	**3**	**4**	**5**

	Supplier Relationships					
SR1	JIT deliveries	**1**	🔴 **2**	**3** 🔵	**4**	**5**
SR2	Open orders	**1**	🔴 **2** 🔵	**3**	**4**	**5**
SR3	Quality at the source	**1**	🔴 **2**	**3** 🔵	**4**	**5**
SR4	Early information exchange on production plans	**1** 🔵	🔴 **2**	**3**	**4**	**5**
SR5	Supplier involvement in quality improvement programmes	**1** 🔵	🔴 **2**	**3**	**4**	**5**
SR6	Reduction of number of sources and distances	**1**	**2**	**3** 🔴	**4** 🔵	**5**
SR7	Long-term contracts	**1**	**2**	**3**	**4** 🔵	🔴 **5**
SR8	Total cost supplier evaluation	🔴 **1** 🔵	**2**	**3**	**4**	**5**
SR9	Supplier involvement in product design and development	**1** 🔵	🔴 **2**	**3**	**4**	**5**
	Customer Relationships					
CR1	Reliable and prompt deliveries	**1**	**2**	**3**	**4**	🔴 **5** 🔵
CR2	Commercial actions to stabilise demand	**1**	🔴 **2**	**3** 🔵	**4**	**5**
CR3	Capability and competence of sales network	**1**	**2**	🔴 **3** 🔵	**4**	**5**
CR4	Early information on customer needs	**1**	🔴 **2**	**3** 🔵	**4**	**5**
CR5	Flexibility on meeting customer requirements	**1**	🔴 **2**	**3**	**4** 🔵	**5**
CR6	Service-enhanced product	🔴 **1**	**2** 🔵	**3**	**4**	**5**
CR7	Customer involvement in product design	🔴 **1** 🔵	**2**	**3**	**4**	**5**
CR8	Customer involvement in quality programmes	🔴 **1** 🔵	**2**	**3**	**4**	**5**

Key 🔴 = Results for Brewery A 🔵 = Results for Brewery B

Figure 5. 1 Results for Brewery A and B

Source: *(Compiled by Researcher)*

The results discussed are those that scored 4 and 5 from either brewery. These represent the lean principles that are currently being used by the breweries to a moderate or large extent to reduce waste and improve quality. These can be used by other craft breweries.

<u>Setup time reduction:</u> Brewery B reduced their set up times by milling on the previous day. This means that on the brew day, the set-up times are reduced as they do not have to prepare for milling.

Error proof equipment: Brewery B used 'error-proof' equipment to a moderate extent. Error proof equipment helps in maintaining quality in that beer is tested during production (e.g. sugar levels) to produce a good quality of beer.

Process capability: Both breweries have processes (e.g. mashing) that yield output within the process specification limits.

Rigorous preventative maintenance: This was carried out during non-production days in brewery B, as stated in their records.

Order and cleanliness in the plant: Brewery B seems to have introduced the concept of orderliness and cleanliness in the brewery to a moderate extent as the brewery was considerably cleaner and tidier than Brewery A, although some work areas, such as the bottling area, were messy.

Visual control of the shop floor: Brewery B used boards to display information to the employees. In addition, the production process was drawn visually to facilitate the employees' understanding of the process.

Pull flow control: Both breweries use this principle to a moderate extent as they function on a pull system. Beer is made as per customer demand.

Few levels of management: Both breweries A and B have fewer levels of management as the brew master is in charge of the brewery and every worker in the brewery reports directly to him.

Multifunctional workers & expansion of autonomy and responsibility: Workers in Brewery A were more multifunctional as the brewer also labelled, bottled and packaged the beer, sometimes with an assistant, thus expanding the responsibility of the workers.

Parts standardisation: Standardization of parts in products, processes, containers, involves eliminating a number of variations in the products or processes and leads to an increased interchangeability of parts as well as greater flexibility (Wild, 2003). Brewery A standardised its parts as all the beer is bottled in the same size bottles, unlike Brewery B that has more than one size of bottles and also a canning line. Both breweries used standardised inputs, such as malts, and processes, such as boiling, to produce different beer products.

Long term contacts: Both brewery A and B have long term contracts with their brewing ingredient suppliers, making it easy for the breweries to plan ahead in terms of cost and pricing and this leads to improved efficiency and communication.

Reduction of number of sources and distances: Reduction of distances lowers transportation costs, whilst a reduction in a number of sources leads to better supplier collaboration. Brewery B adopted this lean principle to a moderate extent by selling its products on-site.

Reliable and prompt deliveries: Both brewery A and B delivered their products on time to their customers.

Flexibility on meeting customer requirements: Brewery B had systems in place to meet customer requirements that were not in the day-to-day requirements. For example, the brewery would work overtime for a specific order. Unlike brewery A, which has no new product, no new markets and does not respond to new user demands, brewery B produces seasonal beers, introduces new flavours and has a functioning sales force that looks for new markets.

These are the lean principles that were employed by the craft breweries to a moderate and/or large extent and can be used to reduce waste and form part of a waste assessment tool. These results are similar to those carried from a previous study by researchers Rose et al. (2011), who demonstrated that the following lean principles can be used to reduce waste: setup time reduction, visual control, cellular layout, standard operation, Kanban, continuous flow, uniform workload, small lot sizes, TQM / TQC, continuous improvement, 5S, quality circles, multifunctional employees, training, teamwork, supplier management and preventative maintenance.

There are also similarities to the results from the research by Matt and Rauch (2013) which indicated that waste can be eliminated by using the following principles and improvement programmes: First in First Out, 5S, benchmarking. Kaizen – continuous improvement, JIT deliveries, pull principle, visual management, zero defects, idea management to utilise the workers' know-how, setup time reduction, value stream mapping, efficient & ergonomic workstations, poke yoke & standardisation, cellular manufacturing, job rotation and low cost automation.

Further, similar conclusions were reached by researchers Belhadi et al. (2016) who pointed out that multifunctional teams, training, pareto analysis, master plan, 5S, value stream mapping, cost deployment, Kaizen, statistical process control, six Sigma, TPM, TOC, Kanban, First In First Out, U-Cell, scoreboard, work standards and knowledge management lean tools and improvement programmes may be used to reduce waste and inefficiencies.

The first objective of the study was to identify appropriate assessment tools that may be used to assess waste in craft breweries. The assessment tool was drawn from the literature as provided by Panizzolo et al., (2012) assisted in identifying the tools which could be used to assess waste in craft breweries.). This tool was identified and tested in the two case studies and was found to be useful. This lean tool can be used by other breweries to assess the level of their leanness, i.e. to measure waste or areas of inefficiencies that occur in their production.

5.3 Research Question 2

What wastes occur in craft breweries?

Waste refers to a process or a step which is not required for an operation and adds no value. The sources of waste include inventory, overproduction, waiting time, unnecessary transporting, processing waste, inefficient work methods, product defects and underutilized human resources (Stevenson, 2012; Douglas, et al., 2015).

As indicated in the literature by researchers Rose et al. (2011), Matt and Rauch (2013) and Belhadi et al. (2016), there are numerous lean tools that may be used to identify waste. One of the most common tools is value stream mapping (Braglia, et al., 2006; Rother & Shook, 2009) that has been used across many industries, for example, the tile industry (Muzunzi, et al., 2013), health-care industry (Machado & Leitner, 2010), paint industry (Rajenthirakumar, et al., 2011), wine industry (Jiménez, et al., 2012) and the automotive industry (Lacerda, et al., 2016). The VSM tool was also used in this study to identify waste and inefficiencies which may occur in craft breweries.

This section first presents the waste and inefficiencies observed from the case study breweries and then discusses these under each source of waste. In addition, proposals are suggested on how these wastes can be reduced or eliminated. The wastes in the two breweries are summarised in Table 5.1.

Table 5. 1 Waste and inefficiencies in case study breweries

	Examples		
Waste	Case Brewery A		Case Brewery B
Inventory	Too much inventory of the wrong malt	Cracked bottes	Cracked bottles lying around
Overproduction	Bottled beer lying around		
Waiting time	Manual bottling	Labelling system faulty	Bottling machine only takes up to 8 bottles
Unnecessary transporting	Poor layout		Untidy work area
Processing waste	Wort boiled for longer than necessary	Pipes/tubes too long	Problem with lauter turn, leading to residual wort in the tun thrown away
Inefficient work methods	Sterilization insufficient	Broken machinery lying around	Flooring unstable at brewing area
	Store room no lights		
Product defects	Fermenter taps not sterilised	Broken gauges	Tripping of electricity flow during production process
	Bottle washer used as bottle cleaner	Mill dirty	
Underutilised HR	Lack of staff training		Work monotonous
			Lack of training
Other inefficiencies	No continuous improvement measures	Pipes/tubes not standard	
		No SOPs for cleaning	

Source: *(Compiled by Researcher)*

i. Inventory

Waste of inventory signifies unnecessary raw stock on hand as well as large amounts of work-in-progress (Hines & Taylor, 2000; Belova & Yansong, 2008; Stevenson, 2012).

The wastes of inventory included an excess of inventory of the wrong malt of brewery A. Only a handful of the malt at brewery A is used during beer production, whilst several 50kg bags were in the storeroom, representing money tied up in inventory.

Brewery B had unprocessed malt left over in the lauter tun, due to faulty machinery but leading to a waste of work-in-progress inventory.

Another source of inventory waste observed was the cracked bottles in both breweries. This could have been due to carelessness in the breweries, or a fault with their suppliers.

These wastes may be eliminated or reduced by:

1. Bringing in raw materials only as they are needed, i.e. using a Just-In-Time (JIT) methodology

Applying the JIT concept will mean that the malt and other inventory are brought in only when they are needed, and thus freeing up money which would have otherwise be tired up in inventory.

2. Fixing the faulty machinery

The lauter tun needs to be fixed so that all the malt is processed and there is no work-in-progress waste, which is currently being thrown away.

3. Quality at source

If the broken bottles were because the suppliers delivered them like that, then inspection should be carried out as the bottles are coming in or returned to suppliers and have them replaced. If they are cracked due to carelessness, then they should be packed in boxes labelled cracked and sent back to suppliers. The cause could not be ascertained during the observation.

ii. Overproduction

Overproduction occurs when more is produced than the customer demands. Overproduction encompasses the unnecessary use of any production resource. It also leads to increased storage as well as longer lead times and unnecessary work-in-progress (Hines & Rich, 1997; Austin, 2013; Stevenson, 2012).

The sources of waste from overproduction that were observed included the bottled beer which was lying around the brewery area. It was still waiting to be packaged and put in the storeroom.

This waste maybe eliminated or reduced in the following ways:

1. Pull flow control

This will allow for production to be pulled by the customer. As the customer demands increase, product must be produced at a greater rate.

2. Takt time

Matching the rate of manufacturing and the rate of demand will mean the right amount of beer is brewed. Takt time measures the rate at which a finished product will need to be finished in order to meet customer demand.

iii. Waiting time

This source of waste requires space and is incurred by products or an order queuing up to be processed. Waiting or idle time can also be a result of unbalanced workloads, unplanned production routines and overstuffing (Agrahari, Dangle, & Chandratre, 2015; Stevenson, 2012).

Both brewery A and B used manual bottling machines which take only eight bottles at a time. During bottling, there is a lot of product queuing up, leading to waiting time.

This waste may be eliminated or reduced by:

1. Investing in automated bottling machinery

This waste could be reduced by investing in an automated bottling machine, which bottles more than eight bottles at a time.

2. Repairs to the labelling machine

This would save wasted time pulling off and reattaching labels or doing them by hand.

iv. Unnecessary transporting

This involves the excessive movement of material, machinery and manpower that are not required for a certain production process. This may be caused by a poor layout and disorganised workplaces (Hines & Taylor, 2000; Douglas, et al., 2015).

For brewery A, the work tools are far from the brewing area, and thus the brewer has to move unnecessarily to get a tool. For example, if the employee required sealing tape for packaging, then he would have to move to the tools area to retrieve such.

These wastes may be eliminated or reduced by improving the layout of the brewery sh so that workers and space are used more efficiently and unnecessary movements of workers and materials are eliminated, as stated by Stevenson (2012).

v. Processing waste

This source of waste is from unnecessary production processes. Scrap is also a source of processing waste. Processing waste occurs when products are over processed, i.e. processed beyond what is required or the set standards. It can also occur when an incorrect product is continuously being processed (Hines & Taylor, 2000; Benson & Kulkarni, 2011; Stevenson, 2012).

Lack of standard operating procedures leads to an estimation of how long processes should run. For example, in the lauter tun, the wort is sometimes boiled for ten extra minutes. In addition to this being over processing, electricity is wasted leading to increased production costs.

The faulty lauter tun at brewery B also caused processing waste, as the remainder of the malt in the tank had to be thrown away.

These wastes may be eliminated or reduced by:

1. Develop standard operating procedures

Developing SOPs would mean work is consistent for every batch of beer produced.

2. Preventative maintenance programmes

The brewery should carry out rigorous preventative maintenance programmes so that such faults are identified and attended too.

vi. Inefficient work methods

Inefficient work methods are wasteful and they decrease productivity. Inefficient work methods involve the unnecessary movement of staff and machinery and may be caused by poor housekeeping, unclear material flow, untrained stuff, and a poor production layout (Wang & Senzen, 2011; Machado & Leitner, 2010; Stevenson, 2012).

Inefficient work methods at brewery A could have been due to the fact that the brewery is disorganised and there is generally poor housekeeping as well as a poor production layout.

Unlike brewery B, the cleaning and sterilization of bottles at brewery A is insufficient. Bottles are washed and not sterilized.

Other forms of sources of waste due to inefficient work methods observed include the lack of sterilization of fermenter tanks (also posing quality problems), leakages and uneven flooring which makes cleaning very difficult and ineffective.

To reduce or eliminate this source of waste:

1. Use of 5S /Housekeeping philosophy

This consists of five activities; sort, set in order, shine, standardise and sustain. Together, these activities are used as a clean-up tool which is used to ensure the work area is logically organised and the same standards are maintained all the time.

2. Layout

An improvement of the layout could also improve the efficiency of the brewery.

3. Proper sterilisation methods

Proper sterilisation of bottles should be done, not just washing. Poor sterilisation might lead to poor quality of beer.

<u>vii. Product defects</u>

This waste involves any quality problems in production that will require a rework or causes the products to be scrapped (Hines & Taylor, 2000; Wang & Senzen, 2011).

Sources of product defect wastes stem from production problems. For example, brewery B electricity flow often trips during production. This poses a huge threat to the quality of the beer and might cause the beer to be regarded as scrap.

These wastes may be eliminated or reduced by:

1. Fixing the electricity flow problem

Constant flow could be ensured by increasing the size of the circuit breakers.

2. Use Standard Operating Procedures (SOP)

This involves designing processes and ensuring that they are always performed to the correct standard. Cleaning procedures are essential in a brewery and failure produces a contaminated product. Scheduled cleaning of taps and all other equipment and proper use of the bottle washer would improve the product supplied to the customer.

viii. Waste of underutilised human resources

This source of waste comes from not fully using the capabilities of the employees in terms of their knowledge and skills (Stevenson, 2012; Douglas, et al., 2015). Unused human potential often results from management policies and management styles that diminish potential employee contributions.

The workers at brewery B have monotonous work and do not seem to be heavily involved in the production process. In both breweries it was noted that the work force lacked training, which leads to low levels of motivation.

This waste may be reduced or eliminated by:

1. Training workers

Providing training for the brewmaster and workers would improve the production and also better motivate the workers.

2. Reconsider the job design

The job design specifies the tasks that constitute a job for a group or for an individual. In order to reduce the waste from underutilised human resources, jobs should include the following characteristics: skill variety, job identity, job significance, autonomy and feedback, as stated by Heizer & Render (2009).

5.4 Research Question 3

Are lean principles appropriate for application in craft breweries and if so, how can craft brewers introduce lean principles in their production processes to improve quality and reduce costs?

Small businesses, in particular craft breweries, should implement lean methodologies using lean principles that are under their control and which can be managed by the limited resources that small businesses typically have, as emphasised by Rose et al. (2010).

In order to answer the third research question, firstly, the lean principles that could be used to reduce waste and costs had to be identified and then a step by step implementation tool provided to answer the "how" question.

Firstly, the feasibility test which was carried out during the study sought to determine which lean principles the breweries could implement under current production capabilities. Secondly, these lean principles were then incorporated into a lean implementation framework designed for craft breweries, together with the principles that were already being applied by the breweries, as presented in section 5.3.

The lean principles that have been described can be used by craft brewers to improve quality and reduce waste.

These lean principles can be introduced into the brewing processes by implementing lean concepts as described in the conceptual framework discussed in the literature review. This framework is extended from the one provided by Belhadi et al. (2016).

Table 5. 2 Summary of lean principles for application in craft breweries

Area of intervention						
Lean principles	Process & Equipment	Manufacturing Planning & Control	Human Resources	Product Design	Supplier relationships	Customer Relationships
	Setup reduction	Small lot sizing	Multifunctional workers	Parts standardization	Quality at source	Reliable and prompt deliveries
	Rigorous preventative maintenance	Visual control of the shop floor	Expansion of autonomy and responsibility		Early information exchange on production plans	Flexibility on meeting customer demands
	Error-proof equipment	Pull flow control	Few levels of management		Long term contracts	
	Order and cleanliness in the plant		Worker involvement in continuous quality improvement programmes			
			Team decision making			
			Worker training			

The discussion below of how craft brewers can implement lean principles is based on the framework shown in Table 5.2.

1. **Map the Process**

The first step involves mapping the process. It is important to note that lean is not focused only on the internal operations, but those of suppliers and customers too. Therefore, in mapping the craft brewing process, inputs (from suppliers) internal processes (transformation) as well as outputs (beer going to customers) are considered. The typical supply chain of a brewery would have suppliers, the brewery and the customers.

The literature discussed the steps for implementing VSM and these can be followed by craft breweries under this first stage of mapping the process. This section identifies the specific lean principles that craft breweries can employ to implement lean.

The value stream should start at the supplier level that provides the inputs, i.e. raw material (malt, yeast, hops, water), support services (refrigeration) and equipment. Lean principles that were identified using the lean assessment tool (LAT) and could be implemented by craft brewers as a starting point under their current production capabilities include: quality at source (SR3) early information exchange of production plans (SR4) and long term contracts (SR7).

Quality at source ensures that work passing at every stage is of a good quality. For example, at each stage of the brewing process, quality at source would ensure that the product passing there would be of good quality. For example, at the first stage of mashing, the malt must be mashed to an extent that is acceptable for brewing standards. If the malt is of poor quality, the end product will be of poor quality too.

Early information exchange of production plans with suppliers ensures that the right set of raw materials are available when they are needed for production. In addition, having long term contracts with suppliers has several advantages including the ease of planning ahead, less administrative work, providing security and building trust between the supplier and buyer.

In the case of craft breweries, communication in the breweries and with customers is facilitated by the small size of the organisation and the direct contact with customers through on-premise sales.

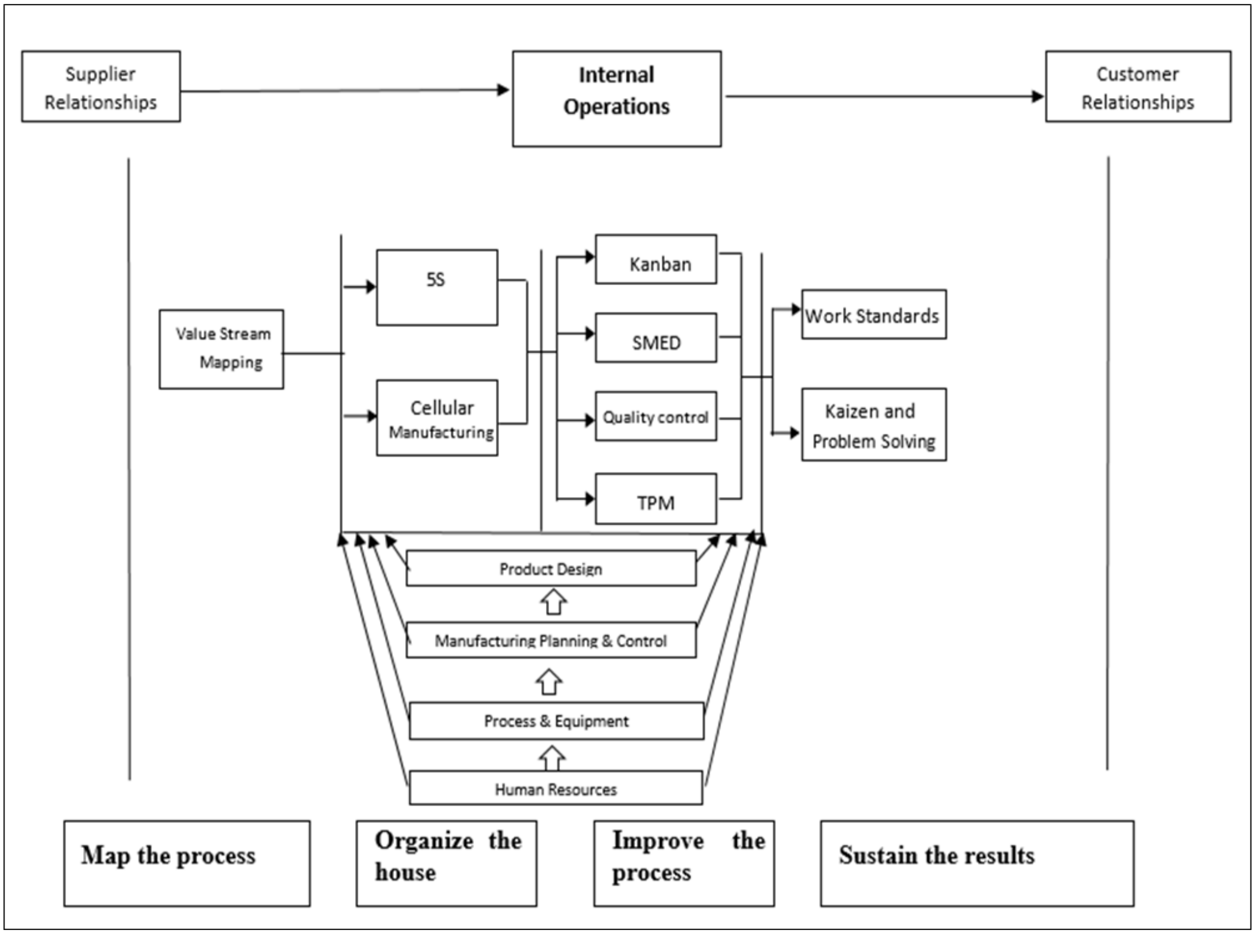


Figure 5. 2 Adapted conceptual framework

Source: *(Adapted by the researcher)*

2. **Organise the House**

As a starting point, the 5Ss/housekeeping philosophy should be applied. The activities involved include sorting, setting in order, shining, standardising and sustaining improvement. The advantages of using 5S lean improvement include improved efficiency, improved safety, a clean and tidy workspace, reduced waste, improved visibility of problem solving and improved productivity.

An area of intervention from the conceptual framework under this second step of organising the house, is process & equipment. The lean improvement programmes which craft brewers can employ include rigorous preventative maintenance (PE4), order and cleanliness in the plant (PE8) and continuous reduction of cycle time (PE9).

Rigorous preventative maintenance ensures that maintenance is frequently performed to check that machinery is functioning properly and that it does not fail unexpectedly. All brewing machinery, e.g. mash tun, lauter tun must be checked frequently to lessen the likelihood of it failing during production.

Ensuring order and cleanliness in the plant is part and parcel of the 5S/Housekeeping philosophy which has just been discussed. Lastly, a commitment must be made for a continuous reduction of cycle time. This may be done by ensuring all machinery runs smoothly and processes are not performed longer than they should.

3. **Improve the Process**

Lean principles for improving the brewing process that may be used include Kanban, quality control and total preventive maintenance.

The Kanban system allows for a visual management of the workflow and the actual workflow, making it easier to identify bottlenecks in the brewing process. Applying quality control measures, e.g. poke yoke, and quality at source will ensure that at every stage of brewing, the beer is of a good quality, leading to a good quality end product.

Total productive maintenance (TPM) overlaps the two steps of organising the house and improving the process. As already discussed, preventative maintenance is proactive and ensures the smooth running of machinery within the brewery.

Additional lean techniques that can be employed to improve the process are shown in Table 5.3.

Table 5. 3 Additional lean techniques to improve the process

Areas of Intervention	**Improvement Programmes**
Manufacturing Planning & Control	small lot sizing, visual control of the shop, pull flow control
Human Resources	multifunctional workers, expansion of anatomy and responsibility, few levels of management, worker involvement in continuous quality improvement programmes, team decision making and worker training
Product Design	Parts standardisation

4. **Sustain the Results**

Work standards as well as kaizen (continuous improvement) and problem-solving programmes must be implemented to improve and sustain the results. Kaizen seeks to constantly improve the processes in production. Having systematic reviews will ensure that standards are maintained and improved.

Developing standard operating procedures (SOPs) is recommended to ensure effective work standards (Earley, 2013; Tapping and Shuker, 2003). SOPs are documented practices designed to ensure that the production process is consistent at all times. SOPs reduce errors and variations in production processes.

The SOPs should be as simple as possible and should include information on:

- Supply management e.g. contracting suppliers
- Scheduling
- Pre-brewing activities
- Production/Brewing
- Cleaning and Sanitisation
- Chemical Safety
- Equipment safety
- Personnel

Although the brewing activities for craft brewers are typically similar, the processes and methods of operation are not the same. Hence each brewery should formulate its own standard operating procedures and continually review these.

5.5 Framework for Implementing Lean in a Craft Brewery

An industry specific lean implementation framework that can be followed by craft brewers, introducing lean tools and lean improvement programmes as discussed, is presented in Figure 5.3.

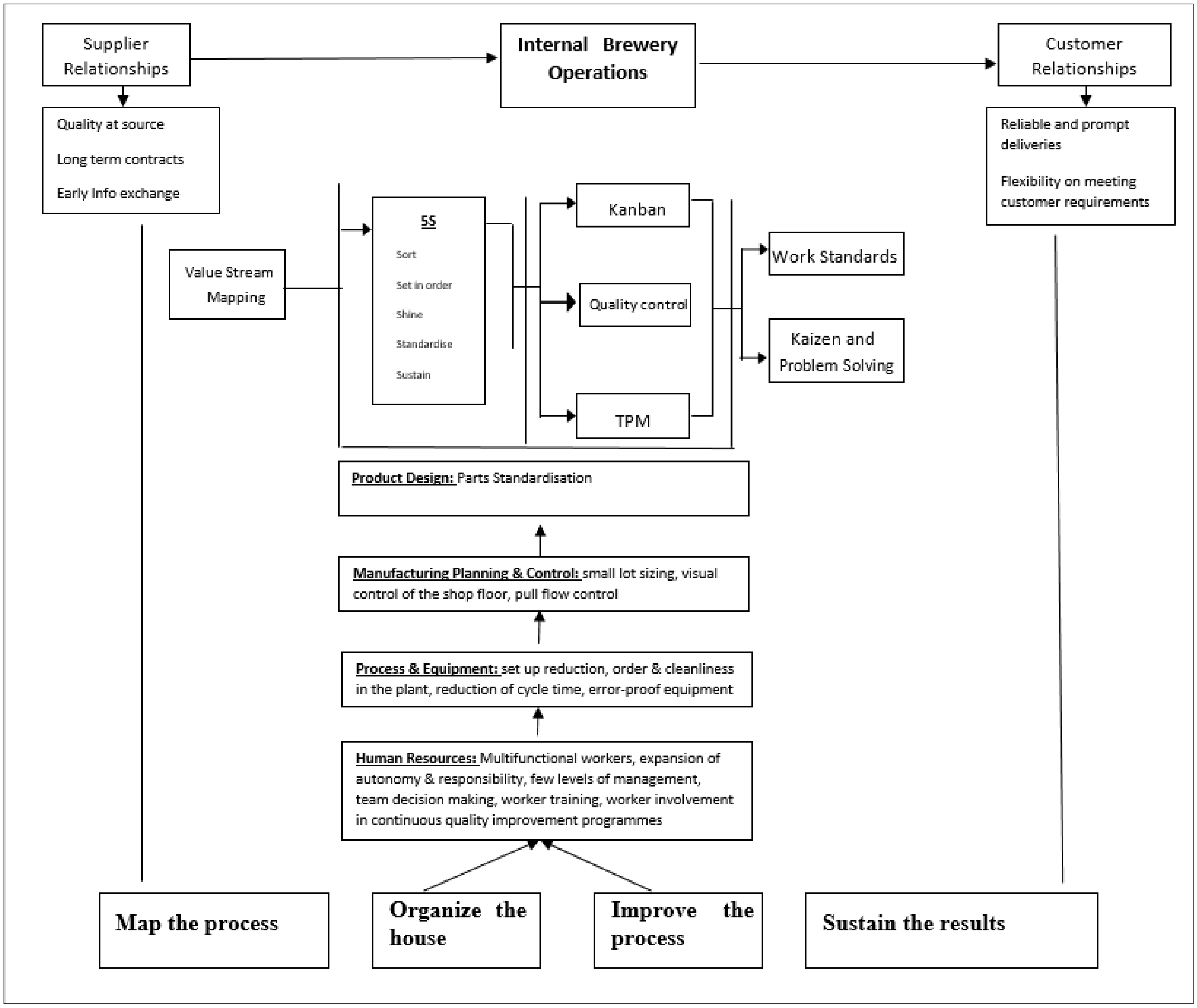


Figure 5. 3 Lean Conceptual Framework for Craft Brewers

Source: *(Compiled by Researcher)*

5.6 Implications of findings and results for research, theory and practice

The implications of these findings and results are discussed on three specific levels namely: implications for this research, for theory and for practice. Firstly, summary statements of the findings are provided and then the implications are discussed.

5.6.1 Summary statements of the findings:

1. Lean tools, like the Lean Assessment Tool, which assess several lean practices (*e.g. setup time reduction, visual controls*) may be used to measure waste in craft breweries
2. The sources of wastes and inefficiencies which were identified from the case studies come from inventory, overproduction, waiting time, unnecessary transporting, processing waste, inefficient work methods, product defects and underutilised human resources
3. Identifying lean principles that the company can implement under its current production capabilities is a key success factor to becoming a lean organisation
4. Having a step by step implementation model which is clear to follow will help companies to follow a logical progression towards lean production.
5. To produce a good quality beer, the ingredients used must be of good quality. Also, monitoring the process, the times and the temperatures closely, is essential
6. The current challenges in craft beer industry include high levels of competition from the main stream beer producing giants, distribution problems, maintaining quality and consistency and marketing and reaching the market pool

5.6.2 Implications for research

The findings from the analysis helped in answering the main questions of this research which were:

1. What tools may be used to assess waste in craft breweries?
2. What wastes occur in craft breweries?
3. Are lean principles appropriate for application in craft breweries and if so, how can craft brewers introduce lean principles in their production processes to improve quality and reduce costs?

From the findings, the researcher identified the lean principles that may be used to assess and identify which wastes occurred at the case study craft breweries. Furthermore, from these results, the researcher could suggest ways in which the case study breweries as well as other breweries could implement the lean methodologies.

5.6.3 Implications for theory/literature

Lean theory can be considered from two perspectives. Firstly, lean seeks to eliminate waste which represents unproductive resources which can be freed up for more productive use. Secondly, lean systems seek to eliminate disruptions, and therefore create a smooth flow.

This study sought to explore the potential for small, independent craft breweries to improve quality and reduce costs through the implementation of lean production methods. Consistent with lean production theory, these results confirm that the introduction of lean methodologies can lead to benefits which include reduced operational costs and improved quality. When applying the lean theory to the data, many useful outcomes were observed.

This research added to the literature providing an implementation model for SMEs in the drinks industry. As discussed earlier, lean implementation in South African industries is not tailored to fit each local industry (Dondofema, Matope, & Akdogan, 2017). Therefore, this research sought to address the problem of selecting the right lean principles for a drinks SME so as to reduce costs and improve quality. Also, it sought to establish how best to implement these elements and provide an easy to use implementation model specific to SMEs in the drinks industry.

Considering the literature, similar studies have been carried out on the implementation of lean production methodologies in various industries and the results are mostly similar to this study.

Rajenthirakumar et al. (2011) conducted a case study in the paint industry. They implemented a lean tool, value stream mapping (VSM), to reduce and eliminate waste from production on the shop floor. The results indicated a reduction in cycle time and increased efficiency. In addition, some non-value adding activities were minimised. Their results have demonstrated that employing VSM to reduce waste is beneficial and improves efficiency. By comparing these results to this study, the impact and benefits of employing VSM as a lean tool can be determined for craft breweries, i.e. the reduction of cycle time, minimisation of non-value adding activities (waste) and increased efficiency.

Other studies, for example, the study by Rahman and Karim (2013), have shown that employing VSM and other lean tools identifies the wastes and inefficiencies in the production process. This research has verified that using VSM produces similar results, i.e. it assists in identifying the wastes and efficiencies in the brewing process.

When comparing these results to those of older studies, it should be indicated that no research on the craft brewing industry or small drinks manufacturers was found by the researcher. However, results from other industries, e.g. the wine industry and the paint industry, have been used to compare these results. Many studies, for example, that of Jiménez et al. (2012), Dhiravidamani et al. (2017) and Lacerda et al. (2016), have reached similar conclusions that implementing lean production principles has numerous benefits that include; improved quality, reduced operational costs, an increase in production output per person, fewer process wastes, decreased lead times, reduced work in progress, less rework and a reduction in finished goods inventory (Melton, 2005; Anand & Kodali, 2009; Singh, Garg, Sharma, & Grewal, 2010) .

In spite of the findings of Deflorin and Scherrer-Rathje, (2012), who argued that lean is not universally applicable and that there is not enough evidence that lean leads to financial benefits, this study found that lean is applicable to the craft brewing industry.

5.6.4 Implications for practice

According to Mohrman and Lawler (2011), for research to impact on practice, the research questions asked must aim to align with practice. In addition, information gained from the research must be shared with the practitioners. The overall research questions were set such that they aligned with practice. The data from the study reveals favourable implications for practitioners in the craft brewing industry.

Pasmore (2013) further states that implications for practice sections should include descriptions of:

a) the problematic issue(s) being addressed

b) the specific audience(s) to which implications are addressed

c) a small number of recommendations about what the audience should/could/should not do based on the research findings

d) an expected outcome of carrying out recommendation(s)

e) some specific illustrations of what carrying out the recommendations might look like, perhaps in narrative form

The study sought to address the problem of selecting the right lean elements in a craft brewery so as to reduce costs and improve quality and how to implement these elements. This was done by conducting lean assessments and feasibility tests on case study breweries to ascertain which lean principles could be used with current production capabilities.

For brewery managers and brew masters, the results from this study suggest a lean implementation model which can be used to introduce lean methodologies in a craft brewery. In addition, they should also try and anticipate ways of predicting and solving future problems which might occur, for example, the threat of water shortages. Anticipating and planning ahead will assist in maintaining production without problems.

Based on the findings, the brew masters and managers should use this model as a guide. Depending on their current production capabilities, they might not have the necessary resources to implement some tools. A staged approach could be used, which implements the more affordable and feasible tools first and puts some of the profits from these interventions back into the more resource-intensive tools. Compared with past studies, implementing lean methodologies proves to be beneficial with regard to:

- Improved quality
- Reduced operational costs
- Increase in production output per person
- Fewer process wastes
- Decreased lead times
- Reduced work in progress
- Less rework
- Reduction in finished goods inventory

These are some of the results that the implementation of lean methodologies might provide for craft breweries.

5.10 Contribution to knowledge

This research sought to contribute to the theory of lean production in SMEs by taking a holistic view of these organisations and their supply chains. It tested the suitability of tools and techniques found in the literature to be used to assess SMEs that compete with large companies with high levels of efficiency to see if lean can improve performance.

In addition, this research aimed to provide an industry-specific set of guidelines that small brewers can use to increase the profitability of their operations. SMEs are an essential part of the South African economy and craft brewers are an example of locally-focused enterprises with the potential to create jobs and contribute to socio-economic development.

5.11 Limitations of the Study

The potential limitations of this study are:

The number of cases: The researcher used two cases in this study. Although the cases were selected for literal replication, which aims to produce more of the same outcomes and provides reassurance that the results are typical, two cases may not be adequate for literal replications.

The research instrument: the research instruments used were adapted by the researcher and therefore might pose a bias threat.

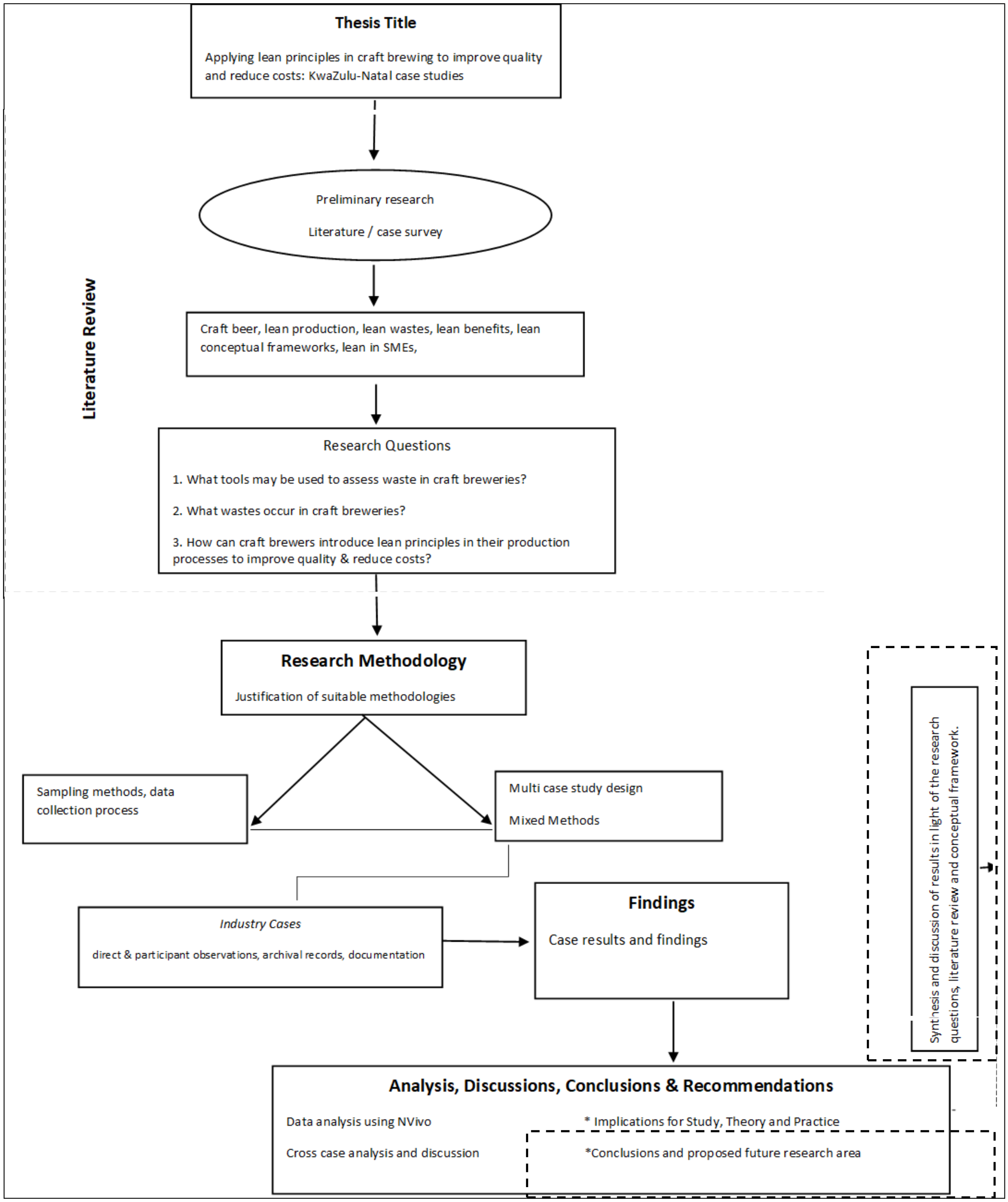
Missing data: some records and documents from the case studies had missing data

Observer bias and error: to reduce observer and error, pre-structured data collection methods were used and minimum interaction in the brewery was maintained by the researcher

Time & financial constraints: due to time and financial constraints, the researcher could only spend a certain amount of time gathering data. This meant some information, such as causes of bottle breakages and interactions with suppliers, could not be probed.

5.12 Chapter Summary

Chapter five discussed the findings of this research. It also discussed the implications of these findings from three perspectives: for the research, for theory & literature, as well as for practice, indicating what the findings mean for these. It compared this study to past studies, indicating how the study is similar and/or differs from other studies. Importantly, it revised the conceptual framework which was used for this study and tied all chapters. Finally, it provided the limitations of the study. The following chapter, chapter 6, concludes the study and offers recommendations as well as areas for future research.


Thesis Title
Applying lean principles in craft brewing to improve quality and reduce costs: KwaZulu-Natal case studies
Literature Review
Preliminary research
Literature / case survey
Craft beer, lean production, lean wastes, lean benefits, lean conceptual frameworks, lean in SMEs,
Research Questions
1. What tools may be used to assess waste in craft breweries?
2. What wastes occur in craft breweries?
3. How can craft brewers introduce lean principles in their production processes to improve quality & reduce costs?
Research Methodology
Justification of suitable methodologies
Sampling methods, data collection process
Multi case study design
Mixed Methods
Industry Cases
direct & participant observations, archival records, documentation
Findings
Case results and findings
Synthesis and discussion of results in light of the research questions, literature review and conceptual framework.
Analysis, Discussions, Conclusions & Recommendations
Data analysis using NVivo
Cross case analysis and discussion
* Implications for Study, Theory and Practice
*Conclusions and proposed future research area

CHAPTER SIX: CONCLUSIONS

6.1 Introduction

The findings of this study were presented and discussed in the previous chapter in an effort to either answer or reject the stated research questions. Possible explanations were also offered for the results that were reported.

This last chapter summarises the results and draws out the conclusions. Further, it will suggest specific recommendations in an effort to introduce clean production of the case study craft breweries and lastly suggests areas for future research.

6.2 Summary of Chapters

Chapter One introduced the thesis by offering a background of the craft brewing industry in South Africa. It also provided the justification of this research, emphasising that SMEs are still under-researched in the field of lean management and yet these organisations are the backbone of the economy and deserve more attention. Furthermore, SMEs in general, and South African craft breweries in particular are poorly served in terms of academic attention and potentially lack the practical guidelines for the implementation of production systems that could potentially ensure their survival in a highly competitive environment, like the beer industry. The problem stated for this research was to *address the problem of selecting the right lean elements in a craft brewery so as to reduce operational costs and improve quality and identifying how these lean elements can be implemented.*

The research questions which this research sought to answer were:

1. What tools may be used to assess waste in craft breweries?
2. What wastes occur in craft breweries?
3. Are lean principles appropriate for application in craft breweries and if so, how can craft brewers introduce lean principles in their production processes to improve quality and reduce costs?

In Chapter Two, the craft beer production process was discussed to better understand the process. The lean theory was also discussed and provided information on how lean principles, practices, tools, techniques and improvement programmes have been implemented in several industries through the examination of cases. It also provided the benefits of implementing the lean methodologies and provided some arguments against this production method. The literature review also highlighted lean tools have been implemented by SMEs and critically identified the ones which could be used in a craft brewery. Importantly, it identified the research gap, which identified that frameworks and lean implementation models had not been tested rigorously in the craft brewing industry or even in SMEs in the drinks industry. Most of the literature specific to the SME sector focused on the growth of the industry and on marketing rather than on production management. The conceptual framework which was used for this study was also discussed in Chapter Two.

Chapter Three discussed the research methodology for the study. This exploratory study followed a multi-case study, mixed method approach, where data was gathered and analysed using both qualitative and quantitative approaches. The data was gathered via instruments of semi-structured interviews, direct observations, participant observation, documentation and archival records. The results and findings were presented and analysed using the SPSS software and NVivo software. The extent of the validity and reliability were discussed, stipulating their importance for case studies. The ethical considerations for the study were also discussed.

Chapter Four presented the findings and results from the data collected. The research questions were used as a guide to present the findings and results, for a clear presentation.

Chapter Five discussed the findings of this research and provided the findings statements for this research. It also discussed the implications of these findings from three perspectives: for the research, for theory & literature, as well as for practice, indicating what the findings mean for these. It compared this study to past studies, indicating how the study is similar and/or differs from other studies. Importantly, it revised the conceptual framework which was used for this study and tied all chapters. Finally, it provided the limitations for the study.

A summary of the three different research questions and the main findings are provided in Table 6.1, as well as the conclusion as to whether the different research questions were answered or unanswered.

Table 6. 1 Summary of Research Questions and Findings

Research question number	**1**
Research question formulated	**What tools may be used to assess waste in craft breweries?**
Main Findings	The literature contains numerous lean tools that are used by companies in different industries. The lean tools that are applicable for small and medium enterprises are identified in the literature. The assessment tool constructed from the literature which was used in this study offers an inclusive tool for assessing waste in craft breweries. The lean assessment tool which was used was developed by the researcher from the work of Panizzolo et al. (2012). Lean tools and lean improvement programmes include: ensuring quality at source, long term contracts, early information exchange, value stream mapping, 5S, Kanban, quality control, TPM, work standards, Kaizen & problem solving, parts standardisation, small lot sizing, visual controls, pull flow, set up reduction, order & cleanliness in the plant, reduction of cycle time, error proof equipment, multifunctional workers, expansion of autonomy & responsibility, few levels of management, team decision making, worker training, worker involvement in continuous quality improvement programmes, reliable & prompt deliveries as well as flexibility in meeting customer demands.
Verdict	The research question was ***answered***

Research question number	**2**
Research question formulated	**What wastes occur in craft breweries?**
Main findings	The wastes that occur in craft breweries were identified using the value stream mapping tool. The sources of the wastes included; inventory, overproduction, waiting time, unnecessary transporting, processing waste, inefficient work methods and product defects and underutilized human resources. The wastes included a faulty labelling systems, insufficient sterilization of bottles, problems with the lauter turn, cracked bottles lying around broken machinery, inefficient bottling machine, untidy work area, poor lighting, unstable flooring, tripping of the electricity flow during production process, pipes/tubes not standard , lack of standard operating procedures for cleaning, lack of continuous improvement measures , dirty mill, too much inventory of the wrong malt, a lack of a facility from preventing leakages, broken gauges, lack of sterilisation of fermenter taps and a poor layout.
Verdict	The research question was ***answered***

Research question number	**3**
Research question formulated	**Are lean principles appropriate for application in craft breweries and if so, how can craft brewers introduce lean principles in their production processes to improve quality and reduce costs?**
Main Findings	The feasibility assessment test was conducted to determine which lean elements and/or improvement programmes in the assessment tool could be introduced or improved in craft breweries to improve quality and reduce wastes. The identified lean elements and improvement programmes made up the lean implementation framework. This implementation framework which was discussed in the study provided a step by step process of implementing lean methodologies in craft breweries The four main steps of the framework included mapping the process, organising the house (brewery), improving the process and sustaining the results.
Verdict	The research question was ***answered***

6.3 Recommendations

Case study breweries A and B can use the implementation framework which was provided by this study in their breweries to improve quality and reduce costs (see p. 134).

When the contents of the literature and the results of the study are analysed, the following specific recommendations for the breweries can be made:

- Housekeeping issues contribute to significant losses for the breweries and the 5S method could achieve waste reduction without significant expense. Hygiene is of enormous importance in brewing and an untidy workplace contributes to this.
- TPM could be implemented to improve the production capacity and to reduce the wastes associated with inefficient work methods. Well-maintained equipment will also produce a better quality product since it will allow proper brewing procedures to be followed.
- Supplier relationships could be developed so that the breweries are able to source quality ingredients to produce good quality beer. At present the quality is variable and this is reflected in the product.
- Integration with suppliers and customers through custom brewery software will improve information flows. This will also support the management of production plans and recipe management.
- Craft brewery managers can benefit from the training offered by institutions such as Lean Institute Africa (LIA), to gain more knowledge from practitioners in lean production, specifically in Africa.
- The human resources in both breweries would benefit from training in brewing and hygiene. This would allow them to perform different roles in the brewery and will provide greater motivation.

6.4 Future Research

- Future research should be expanded to include more craft breweries for the case studies so that the assessment and implementation tools can be tested, developed further and validated. Furthermore, studying other SMEs in the drinks sector would expand the possible application of the tools.
- This may encourage further investigation of how lean production may become a more inclusive business focused component of a company.

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APPENDIX A- SEMI-STRUCTURED INTERVIEW GUIDE

Research Topic: Applying Lean Principles in Craft Brewing to Improve Quality and Reduce Costs: KwaZulu-Natal Case Studies

Mr/Ms/Mrs: ……………………………………………….

Background / Area of expertise: …………………………………………

Interview Questions for Industry Experts

1. **What process are involved in the brewing of craft beer?**

This question aims to understand the processes involved in craft brewing s used (such as milling, mashing, etc) to gain an understanding of the brewing process.

2. **What are the most critical step/area/processes for the production of a good quality of beer and what measures are there to monitor or improve these?**

This question is probing the critical stages of beer production that are of utmost importance in the production of a good quality of beer. Secondly it evaluates what measures are in place for the production of a good quality of beer.

3. **What resources** (e.g. manpower, materials, money***)*** **are used up a lot during production and at what stage of production?**

This question aims to evaluate the processes that use up most of production resources so as to determine if anything can be done to reduce the usage of these resources.

4. **What are the current challenges you are facing in the industry?**

This question is seeking to determine the current challenges faced by the craft beer industry

5. **What improvements might be made in order to reduce the cost of producing craft beer?**

This question is probing the likelihood of improvements that can be made in the production process so as to reduce the overall cost of production.

APPENDIX B –DATA OBSERVATION INSTRUMENT

SECTION A (Current State Assessment)

1. OBSERVE THE PROCESS FLOW OF THE BREWERY

Observe the order of the processes

- Draw the general flow layout diagram of the brewery.

2. CONDUCT VALUE STREAM MAPPING EXERCISE

Collect the information for upstream, internal and downstream activities

Upstream Activities

- Identify the inputs from suppliers

Internal Activities

- Record the process data

Process Being Observed	Equipment	Resources used	Operators	Set up times	Activity time
1. Water Heating					
Process Description					
Information flow					
2. Milling					
Process Description					
Information flow					

3. Mashing					
Process Description					
Information flow					
4. Lautering					
Process Description					
Information flow					
5.Wort Boiling					
Process Description					
Information flows					
6.Fermentation					
Process Description					
Information flows					
7. Bottling					
Process Description					
Information flow					

- Record all wastes and inefficiencies observed

Wastes and Inefficiencies	
✓	✓
✓	✓
✓	✓
✓	✓
✓	✓
✓	✓
✓	✓

Downstream Activities

- Identify of end products to customers

SECTION B

3. LEAN ASSESSMENT

Lean Assessment Tool (LAT)

Using the scale 1= not at all, 2 = to a small extent, 3= to some extent 4 = to a moderate extent, 5= to a large extent, please indicate a response to the following statement, by circling around the number.

Statement: TO WHAT EXTENT HAS THE BREWERY ADOPTED OR USES THE FOLLOWING LEAN PRINCIPLES?

	Process & Equipment					
		Not at all	**To a small extent**	**To some extent**	**To a moderate extent**	**To a large extent**
PE1	Set up reduction	**1**	**2**	**3**	**4**	**5**
PE2	Flow lines	**1**	**2**	**3**	**4**	**5**
PE3	Cellular Manufacturing	**1**	**2**	**3**	**4**	**5**
PE4	Rigorous preventive maintenance	**1**	**2**	**3**	**4**	**5**
PE5	Error – proof equipment	**1**	**2**	**3**	**4**	**5**
PE6	Progressive use of new process technologies	**1**	**2**	**3**	**4**	**5**
PE7	Process capability	**1**	**2**	**3**	**4**	**5**
PE8	Order and cleanliness in the plant	**1**	**2**	**3**	**4**	**5**
PE9	Continuous reduction of cycle time	**1**	**2**	**3**	**4**	**5**

	Manufacturing Planning and Control					
PPC1	Levelled production	**1**	**2**	**3**	**4**	**5**
PPC2	Synchronised scheduling	**1**	**2**	**3**	**4**	**5**
PPC3	Mixed model scheduling	**1**	**2**	**3**	**4**	**5**
PPC4	Under-capacity scheduling	**1**	**2**	**3**	**4**	**5**
PPC5	Small lot sizing	**1**	**2**	**3**	**4**	**5**
PPC6	Visual control of the shop floor	**1**	**2**	**3**	**4**	**5**
PPC7	Overlapped production	**1**	**2**	**3**	**4**	**5**
PPC8	Pull flow control	**1**	**2**	**3**	**4**	**5**
	Human Resource					
HR1	Multifunctional workers	**1**	**2**	**3**	**4**	**5**
HR2	Expansion of autonomy and responsibility	**1**	**2**	**3**	**4**	**5**
HR3	Few levels of management	**1**	**2**	**3**	**4**	**5**
HR4	Worker involvement in continuous quality improvement programmes	**1**	**2**	**3**	**4**	**5**
HR5	Worktime flexibility	**1**	**2**	**3**	**4**	**5**
HR6	Team decision making	**1**	**2**	**3**	**4**	**5**
HR7	Worker training	**1**	**2**	**3**	**4**	**5**

HR8	Innovative performance appraisal and performance related pay systems	**1**	**2**	**3**	**4**	**5**
	Product Design					
PD1	Parts standardization	**1**	**2**	**3**	**4**	**5**
PD2	Product modularisation	**1**	**2**	**3**	**4**	**5**
PD3	Mushroom concept	**1**	**2**	**3**	**4**	**5**
PD4	Design for manufacturability	**1**	**2**	**3**	**4**	**5**
PD5	Phase overlapping	**1**	**2**	**3**	**4**	**5**
PE6	Multifunctional design teams	**1**	**2**	**3**	**4**	**5**
	Supplier Relationships					
SR1	JIT deliveries	**1**	**2**	**3**	**4**	**5**
SR2	Open orders	**1**	**2**	**3**	**4**	**5**
SR3	Quality at the source	**1**	**2**	**3**	**4**	**5**
SR4	Early information exchange on production plans	**1**	**2**	**3**	**4**	**5**
SR5	Supplier involvement in quality improvement programmes	**1**	**2**	**3**	**4**	**5**
SR6	Reduction of number of sources and distances	**1**	**2**	**3**	**4**	**5**
SR7	Long-term contracts	**1**	**2**	**3**	**4**	**5**

SR8	Supplier involvement in product design and development	**1**	**2**	**3**	**4**	**5**
	Customer Relationships					
CR1	Reliable and prompt deliveries	**1**	**2**	**3**	**4**	**5**
CR2	Commercial actions to stabilise demand	**1**	**2**	**3**	**4**	**5**
CR3	Capability and competence of sales network	**1**	**2**	**3**	**4**	**5**
CR4	Early information on customer needs	**1**	**2**	**3**	**4**	**5**
CR5	Flexibility on meeting customer requirements	**1**	**2**	**3**	**4**	**5**
CR6	Service-enhanced product	**1**	**2**	**3**	**4**	**5**
CR7	Customer involvement in product design	**1**	**2**	**3**	**4**	**5**
CR8	Customer involvement in quality programmes	**1**	**2**	**3**	**4**	**5**

4. FEASIBILITY OF LEAN APPLICATION

Lean Application Feasibility Tool

Using the scale 1=very difficult, 2=difficult, 3=neutral, 4=easy, 5=very easy, indicate a response to the following statement, by circling around the number.

Statement: HOW FEASIBLE WILL IT BE TO IMPROVE OR MAKE CHANGES TO THE DIFFERENT LEAN PRINCIPLES?

	Process & Equipment					
		Very Difficult	**Difficult**	**Neutral**	**Easy**	**Very Easy**
PE1	Set up reduction	**1**	**2**	**3**	**4**	**5**
PE2	Flow lines	**1**	**2**	**3**	**4**	**5**
PE3	Cellular Manufacturing	**1**	**2**	**3**	**4**	**5**
PE4	Rigorous preventive maintenance	**1**	**2**	**3**	**4**	**5**
PE5	Error – proof equipment	**1**	**2**	**3**	**4**	**5**
PE6	Progressive use of new process technologies	**1**	**2**	**3**	**4**	**5**
PE7	Process capability	**1**	**2**	**3**	**4**	**5**
PE8	Order and cleanliness in the plant	**1**	**2**	**3**	**4**	**5**
PE9	Continuous reduction of cycle time	**1**	**2**	**3**	**4**	**5**

	Manufacturing Planning and Control					
PPC1	Levelled production	**1**	**2**	**3**	**4**	**5**
PPC2	Synchronised scheduling	**1**	**2**	**3**	**4**	**5**
PPC3	Mixed model scheduling	**1**	**2**	**3**	**4**	**5**
PPC4	Under-capacity scheduling	**1**	**2**	**3**	**4**	**5**
PPC5	Small lot sizing	**1**	**2**	**3**	**4**	**5**
PPC6	Visual control of the shop floor	**1**	**2**	**3**	**4**	**5**
PPC7	Overlapped production	**1**	**2**	**3**	**4**	**5**
PPC8	Pull flow control	**1**	**2**	**3**	**4**	**5**
	Human Resource					
HR1	Multifunctional workers	**1**	**2**	**3**	**4**	**5**
HR2	Expansion of autonomy and responsibility	**1**	**2**	**3**	**4**	**5**
HR3	Few levels of management	**1**	**2**	**3**	**4**	**5**
HR4	Worker involvement in continuous quality improvement programmes	**1**	**2**	**3**	**4**	**5**
HR5	Worktime flexibility	**1**	**2**	**3**	**4**	**5**
HR6	Team decision making	**1**	**2**	**3**	**4**	**5**
HR7	Worker training	**1**	**2**	**3**	**4**	**5**
HR8	Innovative performance appraisal and performance related pay systems	**1**	**2**	**3**	**4**	**5**

	Product Design					
PD1	Parts standardization	**1**	**2**	**3**	**4**	**5**
PD2	Product modularisation	**1**	**2**	**3**	**4**	**5**
PD3	Mushroom concept	**1**	**2**	**3**	**4**	**5**
PD4	Design for manufacturability	**1**	**2**	**3**	**4**	**5**
PD5	Phase overlapping	**1**	**2**	**3**	**4**	**5**
PE6	Multifunctional design teams	**1**	**2**	**3**	**4**	**5**
	Supplier Relationships					
SR1	JIT deliveries	**1**	**2**	**3**	**4**	**5**
SR2	Open orders	**1**	**2**	**3**	**4**	**5**
SR3	Quality at the source	**1**	**2**	**3**	**4**	**5**
SR4	Early information exchange on production plans	**1**	**2**	**3**	**4**	**5**
SR5	Supplier involvement in quality improvement programmes	**1**	**2**	**3**	**4**	**5**
SR6	Reduction of number of sources and distances	**1**	**2**	**3**	**4**	**5**
SR7	Long-term contracts	**1**	**2**	**3**	**4**	**5**
SR8	Supplier involvement in product design and development	**1**	**2**	**3**	**4**	**5**

	Customer Relationships					
CR1	Reliable and prompt deliveries	**1**	**2**	**3**	**4**	**5**
CR2	Commercial actions to stabilise demand	**1**	**2**	**3**	**4**	**5**
CR3	Capability and competence of sales network	**1**	**2**	**3**	**4**	**5**
CR4	Early information on customer needs	**1**	**2**	**3**	**4**	**5**
CR5	Flexibility on meeting customer requirements	**1**	**2**	**3**	**4**	**5**
CR6	Service-enhanced product	**1**	**2**	**3**	**4**	**5**
CR7	Customer involvement in product design	**1**	**2**	**3**	**4**	**5**
CR8	Customer involvement in quality programmes	**1**	**2**	**3**	**4**	**5**

APPENDIX C - SEMI-STRUCTURED INTERVIEW GUIDE (WRITTEN RESPONSE)

Research Topic: Applying Lean Principles in Craft Brewing to Improve Quality and Reduce Costs: KwaZulu-Natal Case Studies

Mr/~~Ms/Mrs~~: Anon……………………………………………….

Background / Area of expertise: Consultant, certified Brewmaster

Interview Questions for Industry Experts

1. **What processes are involved in the brewing of craft beer?**

Typically, the brewing of craft beer begins with the conversion of starch in malted barley and other cereals into simple, fermentable sugars. The vast majority of craft brewers buy malted cereal grains (mainly barley but also some wheat and rye), with only a very few craft breweries malting their own grains. Firstly, the malted grain with, in some beer recipes, a small proportion of unmalted, raw grains, is crushed in a 2 or 4 roller mill. The crushed malt consists of approximately 30% husk, 50% fine grits and 20% flour.

The second step is mashing. The crushed malt is poured into a mash tun and mixed with warm water in a ratio that can vary from 1:2 to 1:3.5 (malt:water). Some breweries mash at a single temperature (e.g. 64°C), others have more costly, heated mash tuns that allow the brewer to increase the mash temperature in steps (e.g. 35°C, 62°C and 72°C). Mashing usually takes between 60 and 90 minutes. Thereafter, the mash is transferred to a lauter tun (a vessel with a sieve like bottom) and the mash liquid, termed wort, is drained from the underside of the sieve and pumped back onto the top of the mash. This recirculation continues until the wort runs clear due to the mashed malt acting as a depth filter. The clear wort is then diverted to the brewing kettle. As the wort level in the lauter tun drops to just above the mashed malt, more hot water at 77°C is sprayed onto the surface of the mash (a process termed sparging). The hot sparge water washes all the remaining sugars from the mashed malt. When the sugar level in the last runnings drops below a certain level (generally about 2°Plato) and the kettle is full, lautering is stopped.

The fourth step is boiling the wort in the kettle. After the wort is boiling, one or more additions of hops is/are made. Boiling continues for between 60 and 90 minutes. After boiling the hot wort is pumped to another vessel, termed a whirlpool, or is recirculated in the kettle by pumping into the vessel via a tangential inlet. This causes the wort to rotate in the vessel (whirlpool) and all the materials in the wort that have precipitated during the boil, together with particulate hop material, settle to form a “trub” cone in the middle of the kettle.

After a 10 to 20 minute rest in the whirlpool or kettle, the clear wort is transferred via a heat exchanger to a clean and sterile fermentation tank. The heat exchanger uses cold water (ideally chilled to between 0 and 3°C) to reduce the wort stream to the desired fermentation temperature (±12°C for bottom fermenting lagers and 18 - 25°C for top fermenting ales). Sterile air or pure compressed oxygen is then bubbled into the wort en route to the fermenter and the correct amount of yeast, calculated as the number of cells per millilitre, is added, either in-line or directly to the fermenter. Pitching rates should achieve 4-6 million cells per ml for ales and 8-12 million yeast cells for lagers.

The fermentation tanks are then sealed to prevent infection by other microbes that can contaminate the beer and produce off-flavours. After several hours, the multiplying yeast cells have used up all the oxygen in the wort and in this anaerobic state, their metabolism changes so that they start breaking down the sugars to produce alcohol, carbon dioxide and heat. The CO_2 produced is exhausted by bubbling through a water trap that doesn't allow air to mix with the gas in the fermenter. Ales fermenting at higher temperatures may complete this primary fermentation after only 4 or 5 days, whereas lagers at 12°C may take several weeks before all the fermentable sugars have been metabolised by the yeast.

After primary fermentation is complete, the yeast generally starts to settle to the bottom of the fermenter. The clear beer may then be pumped off into a second vessel, or the yeast can be removed via a bottom drain. The beer, termed green beer, then conditions for a week or longer until a number of undesirable flavours and aromas have dissipated and pleasant new flavours have evolved. With lagers, this process can take up to 3 months and is termed lagering.

Conditioned beer may then be passed through a filter to remove any turbidity, compressed, sterile CO_2 may be dissolved in the beer and the gassed beer is then stored in a bright beer tank (BBT) to await bottling, canning or kegging. Some beers may have a small amount of unfermented wort or sugar and more yeast added prior to bottling. The sugar in this beer then ferments to produce more alcohol and CO_2 that is trapped in the bottle and results in the desired level of carbonation. Packaged beer then awaits shipment or perhaps on-premise consumption if the brewery also serves as a pub.

This question aims to understand the processes involved in craft brewing (such as milling, mashing, etc.) to gain an understanding of the brewing process.

2. **What are the most critical step/area/processes for the production of a good quality of beer and what measures are there to monitor or improve these?**

There are a number of critical production steps that occur prior to the brewing processes. The growing, harvesting and processing of cereals, malt, hops and other ingredients are critical. For example, the malting process can have a substantial influence on the brewing process, brewhouse yield and final beer quality. Ingredient transport and storage conditions (temperature, humidity, exposure to air and possible contamination) can have a marked effect on the ingredients and the final beer that is produced. The quality of the water used for brewing influences the quality of the beer produced. The presence and concentrations of dissolved minerals, chemical and other contaminants, microbes, the dissolved oxygen and chlorine should be determined in the water used throughout the brewery.

Milling of the malt should produce the correct ratio of husks, fine grits and flour. This ratio is influenced by the type of mill used, the condition of the rollers and the width of the gap between the rollers. The milling should be done immediately prior to mashing to prevent oxidation of the exposed malt kernels.

Mashing in with water at the correct temperature should be quick (no more than 10 minutes) and in the correct ratio. Mixing should be thorough to achieve an even mash temperature and there should be no clumps of dry malt in the mash. If a stepped mash is performed (periodic mash temperature increases), the heating should result in a temperature rise of 1°C per minute but be sufficiently even and gentle that "hot spots" don't develop. One method, termed decoction mashing, still used in some European breweries, is to remove a quantity of thick mash from the bottom of the mash tun, boil this separately and then return it to the main mash thereby heating the mash to the desired temperature. However, it is unlikely that there are any breweries in South Africa using this method. Mashing and the enzyme mediated conversion of starch to sugar (as the principle chemical process taking place) is usually complete after 75 to 90 minutes. An iodine test is conducted to determine if all starch has been converted to simple sugars or dextrins.

Lautering, or using a bed of mash to filter the sweet wort and then using hot sparge water to wash out the remaining sugars, is the most problematic and error prone process in brewing. A range of problems may occur. The mash may "stick" or not allow the wort to flow through, the wort may "channel" through the mash bed and result in a turbid wort that causes later beer quality problems, undesirable harsh flavours may be leached from the malt husks and taint the beer or a substantial amount of fermentable sugars may remain in the mash. If the bed of mash in the lauter tun is not an even thickness (is not evenly distributed), this will cause unequal extraction and a reduction in yield. All these problems will adversely affect the quality of the beer, represent a financial loss and, inevitably, protract the entire lautering process, sometimes by several hours. Generally, good beer cannot be made from cloudy wort.

Boiling the wort in the brewing kettle and adding hops is comparatively straightforward. The best, gentlest and most efficient method of heating a kettle uses steam, either by direct steam injection or through a steam jacketed kettle. Direct heating of the wort with a gas flame or with electric heating elements can result in scorching, the increased production of Strecker aldehydes (reducing the beer's shelf life and flavour stability) and darkening of the beer.

After boiling for between 50 and 90 minutes the beer is rested in the kettle for 10 to 20 minutes in order for various protein and polyphenol complexes to form a coarse or hot break. This particulate matter is heavier and settles out well. If the cooling wort is gently recirculated in the kettle or whirlpool, a firm cone of trub will form in the middle of the whirlpool and the clear wort can then be pumped off.

After the clear wort has passed through the heat exchanger to cool to fermentation temperatures, extremely effective hygiene is essential to prevent microbial contamination. All vessels and piping need to be scrupulously clean and sterile. The correct number of viable yeast cells need to be pitched. Under pitching (adding too few yeast cells) results in a delay to the start of fermentation, hence risking opportunistic microbial infections, and will cause a wide variation and inconsistency in the flavour profile of the beer. Competent yeast management that ensures healthy, well-nourished yeast is critical.

All oxygen should have been used by the multiplying yeast within 18 hours to prevent an increase in aldehyde and diacetyl levels. The quality and flavour stability of beer deteriorates if there is any contact with oxygen at any subsequent point until consumption.

Consistency of fermentation temperatures is important in achieving a consistent flavour and aroma profile of a beer. Even relatively small variations (1-2°C) can change the flavour profile of a beer. There are several measurable parameters of beer that need to be monitored throughout the brewing, fermentation and conditioning processes. These include the specific gravity of the beer (amount of unfermented sugar in solution), the bitterness, colour, mashing and fermentation temperatures, number of viable yeast cells per ml, etc.

This question is probing the critical stages of beer production that are of utmost importance in the production of a good quality of beer. Secondly it evaluates what measures are in place for the production of a good quality beer.

3. **What resources** (e.g. manpower, materials, money***)*** **are used up a lot during production and at what stage of production?**

Energy, mainly for heating the brew kettle whilst boiling, represents a substantial cost. Heat losses from poorly insulated vessels and transfer pipes can contribute to unnecessary costs. Similarly, poor insulation of fermenters can result in excessive costs for cooling, particularly in summer. Large volumes of water are used during the brewing process and bottling, in particular, consumes vast amounts of water for rinsing and cleaning.

There are frequent and substantial increases in the cost of good quality brewing ingredients since most of the ingredients are imported and subject to exchange rate fluctuations. The logistics constraints associated with widely distributed suppliers and tempting bulk discounts mean there is a tendency for craft breweries to carry excessive raw material inventory. Trained workers are in very short supply which means good workers may be paid a premium to encourage them not to move on. Poor training and low skill levels can contribute to poor productivity and ultimately, poor quality products.

This question aims to evaluate the processes that use up most of production resources so as to determine if anything can be done to reduce the usage of these resources.

4. **What are the current challenges you are facing in the industry?**

As mentioned in the previous section, the rising cost of imported ingredients, packaging, operational costs and equipment is a major challenge. Secondly, as consumers of craft beers are becoming more discerning, the demand for better quality beers is increasing and poor quality beers may soon prove difficult to sell.

The biggest threat to most craft breweries is caused by poor hygiene at various stages throughout the brewing process. Whole batches of beer can become contaminated and may have to be discarded. Operator mistakes can also result in costly losses. Fluctuating demand and ineffective distributors can make production scheduling difficult. Increasing interest rates and deteriorating exchange rates make holding inventory costly.

This question is seeking to determine the current challenges faced by the craft beer industry

5. **What improvements might be made in order to reduce the cost of producing craft beer?**

Better trained workers, and the implementation of more effective brewing practices, with clearly defined SOPs, should contribute to substantial improvements. Also, there needs to be more effective process control, to provide more effective early warning and to enable more consistent production and more consistent product quality.

This question is probing the likelihood of improvements that can be made in the production process so as to reduce the overall cost of production.

APPENDIX D – INFORMED CONSENT

UNIVERSITY OF KWAZULU-NATAL
School of Management, IT and Governance

Dear Respondent,

Research Project

Researcher: Sindisiwe Mahlangu (Telephone number: 0738911014) (Email: siemanzue@gmail.com)

Supervisor: Dr. Salisbury (Telephone number: 033-260-5458) (Email: Salisbury@ukzn.ac.za)

Research Office: Humanities & Social Sciences Research Ethics Administration, Govan Mbeki Building, Westville Campus, Tel: + 27 (0)31 260 8350, Email: hssreclms@ukzn.ac.za

I, Sindisiwe Mahlangu am a Master of Commerce student in the School of Management, IT and Governance, at the University of KwaZulu-Natal. You are invited to participate in a research project entitled: *Applying Lean Principles in Craft Brewing to Improve Quality and Reduce Costs: Two KwaZulu-Natal Case Studies*

The aim of this study is to identify any wastes that may occur during the brewing process and, using appropriate lean tools, determine how to reduce costs and improve beer quality in a craft brewery.

Your participation in this project is voluntary. You may refuse to participate or withdraw from the project at any time with no negative consequence. There will be no monetary gain from participating in this research project. Confidentiality and anonymity of records will be maintained by the researcher and the school of Management, IT and Governance, UKZN. All collected data will be used solely for research purposes and will be destroyed after 5 years.

This study has been ethically reviewed and approved by the UKZN Humanities and Social Sciences Research Ethics Committee (approval number_____).

The interview should take about 15minutes/s to complete. Thank you for your time.

Sincerely

Researcher's signature___________________________________ Date_________________

UNIVERSITY OF KWAZULU-NATAL
School of Management, IT and Governance

Research Project

Researcher: Sindisiwe Mahlangu (Telephone number: 0738911014) (Email: siemanzue@gmail.com)

Supervisor: Dr. Salisbury (Telephone number: 033-260-5458) (Email: Salisbury@ukzn.ac.za)

Research Office: **Humanities & Social Sciences Research Ethics Administration, Govan Mbeki Building, Westville Campus, Tel: 27 31 2604557, Email: HSSREC@ukzn.ac.za**

CONSENT

I____(full names of participant) hereby confirm that I understand the contents of this document and the nature of the research project, and I consent to participating in the research project. I understand that I am at liberty to withdraw from the project at any time, should I so desire.

Additional consent, where applicable

I hereby provide consent to:

Audio-record my interview YES / NO

____________________ ____________________

Signature of Participant Date

APPENDIX E – ETHICAL CLEARANCE APPROVAL LETTER

UNIVERSITY OF KWAZULU-NATAL™
INYUVESI YAKWAZULU-NATALI

14 March 2018

Ms Sindisiwe Mahlangu (212545122)
School of Management, IT & Governance
Pietermaritzburg Campus

Dear Ms Mahlangu,

Protocol reference number: HSS/0184/018M
Project title: Applying Lean Principles in Craft Brewing to improve Quality and Reduce Costs: Two KwaZulu-Natal case studies

Approval Notification – Expedited Application

In response to your application received on 06 March 2018, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application and the protocol has been granted **FULL APPROVAL.**

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number.

PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

Naidoo
Dr Shamila Naidoo (Deputy Chair)

/ms

Cc Supervisor: Dr RH Salisbury
Cc Academic Leader Research: Professor Isabel Martins
Cc School Administrator: Ms Debbie Cunynghame

Humanities & Social Sciences Research Ethics Committee
Professor Shenuka Singh (Chair)
Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Telephone: +27 (0) 31 260 3587/8350/4557 **Facsimile:** +27 (0) 31 260 4609 **Email:** ximbap@ukzn.ac.za / snymanm@ukzn.ac.za / mohunp@ukzn.ac.za
Website: www.ukzn.ac.za

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