Evaluation of Production Outsourcing Effectiveness in the Rolling Stock Manufacturing Sector

Submitted in fulfillment of the requirements

of

Master of Engineering

in the Faculty of Engineering and the Built Environment

at the Durban University of Technology

Sakhiwo Boyce

21959872

August 2023

Supervisor: Dr. O A Olanrewaju

Declaration

I hereby declare that this study is my own work, and it does not contain material that has been published already or written by another student or researcher. This material has not been accepted for any award of any former degree at Durban University of Technology or any other educational institution. Furthermore, I declare that the academic content of this theory is my own creation of work. The study company support, or contribution made has been clearly acknowledged in the thesis.

Student: Mr Sakhiwo Boyce (21959872) _____ Date: 17 August 2023

Supervisor: Dr Oludolapo Akanni Olanrewaju _____Date: 17 August 2023

Acknowledgements

First and foremost, I would like to express my sincere gratitude to my supervisor Dr Oludolapo Akanni Olanrewaju for the endless and continued support of my Master of Engineering study and research. I would also want to thank him for his motivation, patience, immense knowledge and enthusiasm. Without his guidance, I could have not made it in writing this research thesis. I would also like to thank my fellow classmates for all the support we shared among each other during this journey. Not forgetting to thank all my colleagues who participated in my research, then to my parents who inspired me to pursue this qualification. Lastly, I would also like to thank my wife, my two sons and daughter for enabling me to leave a purposeful life.

Abstract

Outsourcing is referred to as transferring an activity internally to external control. Production outsourcing is the contracting with a third party to produce goods or services (Valiyattoor and Bhandari 2020). This thesis studies production outsourcing and in-house production in the rolling stock manufacturing sector through a manufacturer and supplier perspective.

On various occasions the organization experienced challenges in meeting monthly targets, as well as producing at a high cost. Some of the causes for this were not obvious to management, but production outsourcing was a suspected possible factor but the influence on overall production costs had to be investigated where it is positive or negative.

The aim of the study was to evaluate the cost to outsource vs in-house production. Furthermore, assess production outsourcing influence in the changing demand patterns and its influence on customer satisfaction.

A DMAIC (an abbreviation for Define, Measure, Analyze, Improve and Control) lean six sigma methodology was adopted in creating the framework design. The research study is quantitative that follows descriptive approach, where historical data from SAP (Systems, Analysis and Products in data processing) and data collected from survey was analyzed and evaluated. The sample size that was used for the first objective was a total of 36 components drawn from 6 various businesses data base, namely: coaches, wagons, rolling stock equipment (RSE), wheels, locomotives, and ports. The sample size used for the second objective was 40 respondents from AB Ltd manufacturing facility, where 440 responses were received.

For objective two, the data was exported to Microsoft excel. A chi-square test method was employed to analyze the data, using both Microsoft excel and Statistical Package for the Social Sciences (SPSS) software. For the second aspect to address the second objective, 5-point Likert Scale technique to collect and gather responses was used. Data analysis method used was a t-test using both Microsoft Excel and Statistical Package for the Social Sciences (SPSS) software. Both tests completed were hypothesis test, one being chi-square and one being a t test.

In addressing objective one, the study results aided the researcher to draw conclusions that the cost rate of insourced parts differs to that of outsourced part. This

therefore means that production outsourcing does not necessarily reduce production costs for AB Ltd. The results show that in-house production is cheaper compared to outsourcing. In addressing objective two, the study results endorsed the researcher to draw another conclusion that production outsourcing does not have positive influence in managing and supporting increased customer demands. This was based on the null hypothesis that was rejected in both aspects; hence the study supported the alternative hypothesis. The recommendations were that; AB Ltd should outsource the right components; no outsourcing should be implemented for parts that will have direct impact on AB Ltd's customers and lastly, not to consider cost only as a main reason to outsource.

Table of Contents

List of Figures

List of Tables

Appendices

List of Acronyms

1. CHAPTER 1: INTRODUCTION

1.1 Introduction

Manufacturing companies undertake a wide range of supply chain initiatives in order to find a better way to increase performance. One of these initiatives is outsourcing production, measuring its overall operational performance and its components. This can be done by firstly measuring the product's raw materials and purchased item's order lead–times, manufacturing cycle time and operating equipment effectiveness (Kenyon, Meixell and Westfall 2016). On a study from the United States, (US) there is great re-shoring in procurement of components, material and services by returning back production and service functions back to the US (Abriyantoro *et al.* 2019).

Also, in a study conducted at Eskom (South Africa's power utility provider) Distribution South Africa; results showed that outsourcing of core business deliverables has an influence on the business performance. There was also a positive impact on internal employees' motivation by outsourcing core business deliverables at Eskom Distribution South Africa (Magagula 2017).It is common that management in manufacturing firms is faced with a decision-making challenge of whether to outsource or manufacture in-house. Hence, this study is focused on the approach of outsourcing under the production planning and operations management disciplines at AB Ltd.

Outsourcing is one of commonplace method in the U.S for services as well as manufactures service providers, mainly due to increased supply chain competitiveness of the global environment (Coyle 2017). A study showed that one-third of US businesses plan was to move goods and services work back to the US during the next coming 12 months starting from January 2015 the following year (Bond 2014). This trend is due to disappointment in the results of original outsourcing decision together with the changing global cost structure (Hagerty 2012). However, since 2008, South Africa had come to be one of the forthcoming offshore destinations for business process outsourcing (BPO). The estimated market was 182 billion dollars globally by 2013. South Africa was evaluated as a BPO destination, the research found that for other countries, value proposition is often cheaper (Abriyantoro *et al.* 2019) . The reason is that SA's value proposition is not cost based like other countries but is all about overall economic value, strong cultural compatibility and high quality service and staff (Craig, Lacity and Willcocks 2014).

AB Ltd is one of five operating divisions (ODs) in South Africa(SA); this means that the company belongs to a group of five operating divisions across SA. The other four are AC Ltd, AD Ltd, AE Ltd and AF Ltd. AC Ltd is a freight rail state owned company responsible for moving freight throughout the length and the breath of South Africa. The operating division's (OD's) responsibilities are as follows:

- AC Ltd moves freight through goods trains.
- AD Ltd is the landlord for all operating divisions.
- AE Ltd is responsible for shipment of goods.
- AF Ltd is responsible for moving goods underground.

AC Ltd's core business is to manufacture and refurbish components, subcomponents and sub-assemblies from raw material and parts, convert them into final products such as locomotives, wagons and straddle carriers. These products are then supplied to other operating divisions mostly AC Ltd, which is a customer for the locomotives and wagons as well as to other external customers in the South African mining industry.

The study focused on outsourcing, which is a practice used to reduce costs by transferring some portions of work to external suppliers rather than completing work in-house (Arnold 2000). There are also two existing theories that contributed to the study which were useful during the investigation. It was the third-party logistics (3PL) theory and the purchasing and supply management (PSM) theory. High production cost gaps identified in these theories led to the proposal of the new study that was completed.

It was found that firms involved in outsourcing their production activities experienced a reduction in manufacturing cycle times, moderate increase in customer order lead times. This has resulted in moderate, but significant decrease in on time delivery rates (McCarthy and Anagnostou 2004). It was then fair to select existing papers around outsourcing because solutions to high production costs were still not entirely available and unclear. The results of the study will therefore be very valuable to AB Ltd senior management as well rail manufacturing sector in production and operations management decision-making as well as to other researchers.

Since the study followed outsourcing under production planning and control (PPC) approach, it was important to introduce the approach. Production planning and control (PPC) are strategies that work together in the manufacturing processes. What to produce, how much to produce, when to produce is what is involved in production planning. Production control is the use of technical techniques throughout the production system in order to optimize performance to realize throughput results (Dahlgrün and Bausch 2019).

The diagram below demonstrates the relationship between production planning and control.

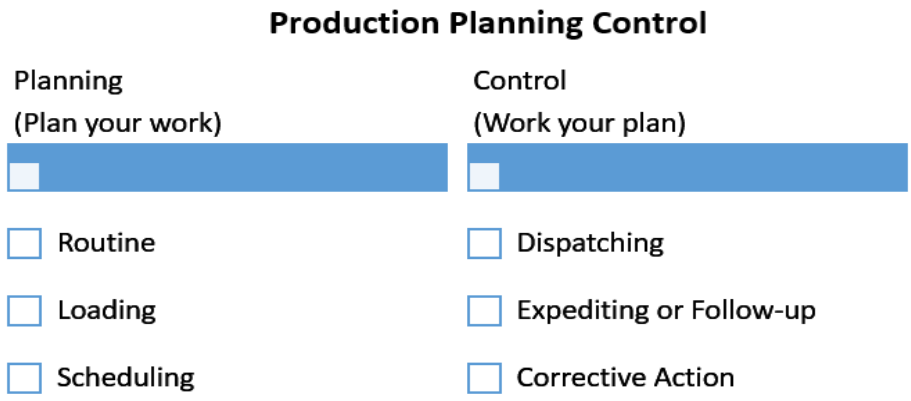


Figure 1-1 Production planning and control

Source: (Nikos I. Karacapilidis 1996)

1.2 Problem Statement

On several occasions, AB Ltd has been faced with risks of not meeting its monthly targets as well as producing products at a high cost. This was due to a various number of uncertain that include inefficient production outsourcing practice, short supply of subcomponents to the production line due to machine breakdowns, longer process times, higher operating costs and longer raw material lead times from external suppliers. Therefore, this gap has been identified to conduct a study on this reoccurring

problem in the organization. In some occasions, some components are outsourced but production targets are still not met at the end of the day due to either late deliveries, poor quality or other reasons.

1.3 Significance of the Study

The importance of the study is to assist AB Ltd senior management in making decisions around production outsourcing. The study will also assist the rail manufacturing sector especially management responsible for production planning and operations management. The study will also show the extent in which outsourcing affects operating costs, its influence in production costs and detail on how it supports increased demand. The paper will also give AB Ltd management an understanding on when, how, and what to outsource.

1.4 Research Questions

1.4.1 Main Research Question

How effective is production outsourcing in increasing production efficiency?

1.4.2 Hypothesis Statements and Research Questions

Hypothesis statement 1: Production outsourcing cost is the same as in-house production cost.

Hypothesis statement 2: Production outsourcing has influence in managing and satisfying increased customer demands.

- Can production outsourcing reduce operating costs?
- Does production outsourcing provide a flexible solution to address changing demand patterns?
- Can production outsourcing have an influence on customer satisfaction?

1.5 Aim of The Study

The aim of the study is to evaluate the production outsourcing effectiveness in the rolling stock manufacturing sector. A study was initiated and conducted in order to determine whether benefits of production outsourcing exist in the organization. Since most outsourcing decisions are motivated by cost factors, the study focused on different businesses that produce various types of products for the rail industry at AB Ltd.

1.6 Objectives

The objectives of the study are:

- To investigate how outsourcing could reduce production cost.
- To investigate if outsourcing has an influence on managing and satisfying increased customer demands.

1.7 Research Methods

The research approach that was employed in this study was a mixed method. Since the study has two objectives, it also adapted two methods per objective. However, overall, the study is classified as a fundamental type of research (Harland et al., 2005). It focuses on addressing the problem of inefficiency as far as production activities are concerned at AB Ltd. The reason for selecting this type of approach was the need to measure variables and perform hypotheses testing (Khademi 2015). There was also a need to understand the production flow and lastly obtain customer satisfaction opinion from employees at TE Durban. The methods focused on the examination of production and outsourcing cost, processing times, order lead times and a set of questions asked from the population.

For objective one, looking at historical data by obtaining records of parts that are manufactured in-house, outsourced, as well procured externally from suppliers, used document analysis method. Data analysis method was Chi-Square test, which falls under descriptive statistics methods was employed to analyze the variance in cost of outsourcing versus in-house production

For objective two, a link via email, of all questionnaires for closed ended questions which was sent to the company employees of the six different businesses in the plant was used. Feedback was summarized after a Likert Scale technique was used by the participants to mark the levels of agreement, where 1 is strongly disagree and 5 is strongly agree (Norman 2010). Analysis method used was hypothesis *t*-test for descriptive statistics analysis.

Table 1-1 Objective vs method used

Objective no.	Objectives	Collection and Analysis Methods
Objective 1	How outsourcing can reduce production costs.	Document analysis: Historical data of outsourced parts and assemblies was obtained from Systems, Applications & Products in Data Processing (SAP), then exported to Microsoft excel. A chi-square test method to be employed to analyze the data, using both Microsoft excel and Statistical Package for the Social Sciences (SPSS) software.
Objective 2	Influence of production outsourcing in managing and supporting increased customer demands.	Survey: online questionnaire to get attitudes and opinions from employees about customer satisfaction and outsourcing response to increased demands, using 5-point Likert Scale technique to collect and gather responses. Data analysis method used was hypothesis *t*-test using both Microsoft Excel and Statistical Package for the Social Sciences (SPSS) software.

1.8 Research Scope and Limitations

The purpose of the study was to seek knowledge on the influence of outsourcing production in AB Ltd. The study was conducted at Transnet Engineering division in Durban, Kwa-Zulu Natal (KZN), South Africa. The research scope covered six business units namely: locomotives, coaches, rolling stock equipment (RSE), wheels, wagons and ports. Limitation was on selecting not more than twenty commonly outsourced components per business unit in the past 2 years. Duration of the whole study was completed over twelve month excluding six months of planning. Transnet Engineering has other centers located in other provinces in South Africa (SA)

producing similar components and subassemblies; however, the study was done in the Durban plant only.

1.9 Dissertation Format

This chapter presents the structure of this thesis, which is followed by short description of each chapter.

Chapter 1: Introduction

The introductory chapter addresses the background of the topic and gives an understanding of the context studies. The concept of outsourcing and production planning is also introduced. Collectively, the introduction chapter leads to problem statement, significance of the study, research questions, aims, objectives, research methods and research scope and limitations.

Chapter 2: Literature Review

This chapter covers what was learnt from previous contributors around outsourcing. This chapter will include the overview of theories viewpoint to understand outsourcing in production planning and its driving forces. This is about reviewing a number of sources closely related to outsourcing production.

Chapter 3: Methodology

The methodology of the study is addressed in this chapter. The chosen research approach is discussed giving an overview of the process of the research. Data collection, instruments, data treatment procedures are discussed on this chapters. The chapter ends by summarizing how work was done in ensuring good quality of the study.

Chapter 4: Data Analysis, Interpretation and Discussion of Results

This is where actual findings, validation of results are explained. The discussion on the interpretation of the results were also addressed in this chapter.

This is where concluding remarks of the overall study of are found. It is also where the study indicated whether the objectives were met or not, with regards to the study approach used. Opportunities for further research are also discussed in this chapter. No new data and information is presented in this chapter.

1.10 Conclusion

This chapter has provided a background of the company where the study was conducted. One of the reasons the company's background was given is that the rail sector has limited companies in South Africa (SA), and its processes and products are not obvious to the public and to other parties in the manufacturing sector. This chapter also outlined the background of the study; the research hypotheses identification was also stated. The chapter also introduced the research design and methodology chosen for this study.

2. CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

A survey of selected papers written and published on outsourcing are presented and reviewed in this chapter. This is the chapter where a background of larger works that were previously addressed are discussed in depth. Review from a number of sources closely related to outsourcing was analyzed and synthesized. It is important to also note that not all the literature under outsourcing was explored in this chapter; those literature not relevant were excluded accordingly. Majority, but not all the literature that was explored was around manufacturing firms either. The chapter also reviewed studies that were conducted in other industries that provide services and not goods or tangible products. The reason for reviewing effectiveness of production outsourcing in general is to uncover the extent of work done to establish the contribution of this study. It is also important to note that each source had its own unique contribution. At the end of the review discussion, contradictions, gaps and unanswered questions were noted.

2.2 Defining Outsourcing

Valiyattoor (2020) stated that outsourcing is a practice that falls under management in order to make decision-making units more competitive and productive. Even though outsourcing has been recognized in the strategic management literature in the recent times, its basic principle was portrayed in economic theories many years ago. For example, a division of labour as a source of efficiency via specialization was identified, which eventually could result in economic prosperity. The basic difference between division of labour and outsourcing is that the previous focuses on labour activities that are not beyond a firm, while the latter allows for tapping the benefits of specialization across the firms. He further states that outsourcing occurs when companies have to choose whether to perform activities internal themselves or having those activities performed by others anywhere in the world. Outsourcing can also be an attractive option to internal investment to enhance the development of new capabilities and skills. In some instances, it can be treated as a business strategy of making more by

doing less, lastly it was also found to be an emerging practice among manufacturing units but to two other sectors of the economy called agriculture and services.

There are also many arguments in favor of outsourcing, there is surprisingly few studies that proved after systematical analysis that the outcome of outsourcing on plant performance is excellent. Furthermore, the study was based on a wide-scale survey on a representative sample of Swedish engineering plants. The results displayed no significant effects from outsourcing manufacturing on plant operating performance. Only 5% of plants surveyed achieved significant edits from outsourcing (Bengtsson and Dabhilkar 2008). It is also stated on (Bengtsson and Dabhikar, 2008) study that the outsourcing of support activities has merely any effects of manufacturing performance.

In spite of outsourcing remaining a commanding strategic choice for managers, the understanding of its effect on the company stays deficient. In another study, the focus was on empirical information surrounding contingencies that determine if and in what manner does outsourcing affect the firm's permanence (Lahiri *et al.* 2022). Precisely, the form of value chain activity, core and non-core, nature of industry activity, that is service and manufacturing, and lastly, the provider's location (international and domestic), affect performance. The study conducted a meta-analysis of 121 samples from 106 primary studies, lengthening over 28 years between 1992 and 2019 (Lahiri *et al.* 2022)

Lahiri (2022) also found that outsourcing firm performance is exceptional. In support to the statement, the results showed that the partnership is stronger for non-core outsourcing than core outsourcing. The results also demonstrated that positive relationship is stronger for international outsourcing when compared with domestic outsourcing. Lastly, the results showed that there is no variation across manufacturing and service outsourcing.

2.2.1 Global Outsourcing Strategy

Mazzola (2019) states the effect of global sourcing strategies is also revealed. Consequences of manufacturing outsourcing and captive-offshoring modernizing of the firm were studied. Data from a sample of three hundred and sixty-eight manufacturing firms that were listed on National Association of Securities Dealers Automated Quotations (NASDAQ) stock exchange was collected, and then hypothesis was tested thereafter. In the same breath, it is mentioned that although global sourcing strategies like outsourcing and captive-offshoring has an expanding tendency in manufacturing sector, their influence on a companies' capability to modernize, more likely on new product development is not limited only, however also provides contradictory and confusion debates (Kotabe, Murray and Mol 2008).

The findings were that either in a spot manner or over long period, managers should be familiar of the consequences of outsourcing and captive-offshoring manufacturing (Mazzola, Bruccoleri and Perrone 2019). A need to search for equilibrium by managers between adapting captive-offshoring for a short period compared to many years was needed. There is still a gap as to whether to go for captive-offshoring or manufacturing outsourcing, or both at this stage. At AB Ltd the effectiveness of production outsourcing is still to be studied so results and findings from Mazzola (2019) will contribute positively to the research.

In the same breath, the argument is based on two specific effects which are positive and negative. These effects shape the influence of outsourcing and captive-offshoring strategies on new product developments. As illustrated in Figure 2-1, two aspects within the timeline of adoption of such précises are identified. Perseverance reports excellent circles that arise for the firm if it carries on in applying such practices until the access to external expertise and resources. The persistence reports bad circles the firm experiences when it persists longer in implementing these strategies. While the opposite side of the figure y-axis reflects a situation in which the company follows. Furthermore, reflecting the outsourcing/captive offshore over one year, as well as in an event the company utilizes these strategies for more than one year.

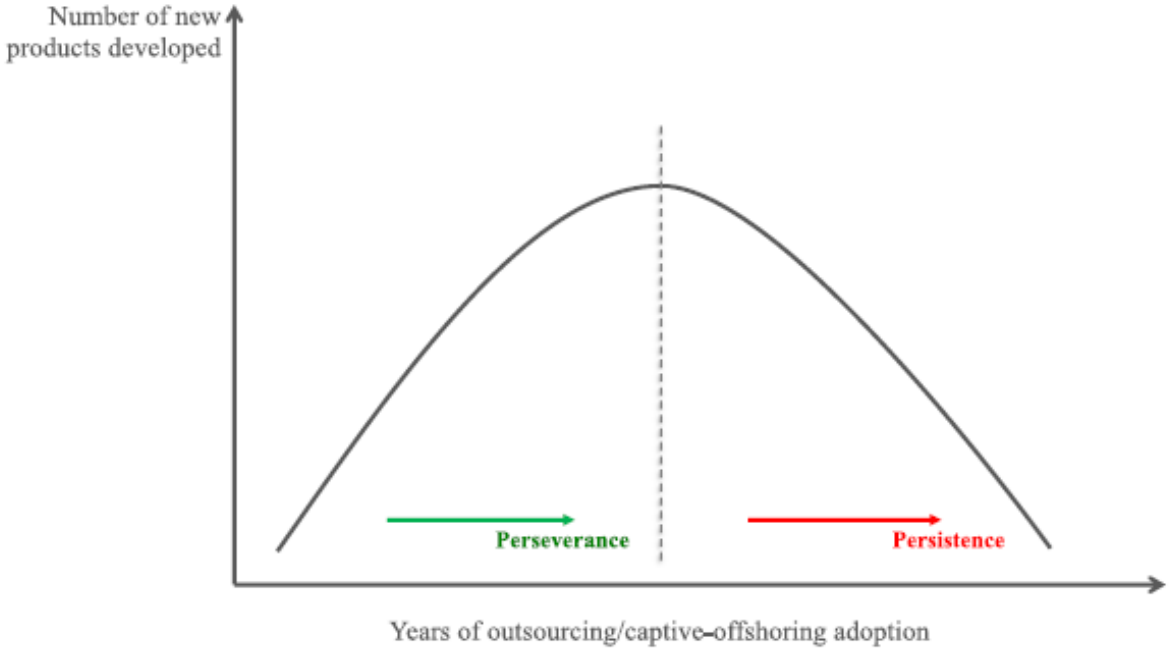


Figure 2-1 Expected effect of keeping outsourcing/captive-offshoring over the years on new product development

Source: (Mazzola, Bruccoleri and Perrone 2019)

2.2.2 Outsourcing Drivers

There are many drivers that seem vail for services, manufacturing and information and communication technology (dictionary) outsourcing. The most popular driver with a proclaimed beneficial result is reduction of cost. There are also some motives that include the release of resources as well investment avoidance. The conceptual understanding of outsourcing is more strategic, it focuses more on core competence and differentiation which allows access to new opportunities to construct faster product development (Bengtsson and Dabhilkar 2008). The theories and models that try to help identify what should be outsourced, what should be kept in-house or insourced. Transaction cost economic (TCE) is used as basis to compare cost of in-house manufacturing and collected cost of buying the corresponding products and services (Ellram and Billington 2001).

The factor that is commonly decisive on whether to outsource or not is asset specificity. The logic behind this is that different investments and assets are similar and precise to a particular plant (Bengtsson and Dabhilkar 2008). The assets and competencies with low specificity stand a higher chance of being outsourced, while assets that have a high specificity are most likely to be kept in-house. In basis for many models, core competence concept is commonly adapted. Characteristics of plant's core competencies are as follows:

- They are rare and particularize the plant from its competitors.
- They are sustainable and difficult to duplicate.
- They may be utilized in various products and markets.

Problems in non-core activities are also as follows:

The candidates of outsourcing are commonly activities that are defined as non-core; however, there are some challenges with this type of model.

- Defining what is rare and differentiating is one of the challenges that is encountered.
- Another problem is that the competencies are active and as a result, the technological and market changes can be unpredictable. This means that the current core may change to non-core tomorrow, vice versa.
- Plant competencies are organized by nature, meaning there is some dependency in between abilities that make the core and the support core activities.

Although the main drivers of outsourcing are generally well known, the question of what explains logistics outsourcing decision with the United Kingdom Uair pharmaceutical manufacturing industry remains researched less (Ali *et al.* 2023). Logistics outsourcing is a practice mostly used by firms to enable them to penetrate capabilities that they lack internally. The study aimed at bridging the above mentioned gap in the literature. The study surveyed 49 drug manufacturers located in the UK,

using a web-based questionnaire. Logistics regression, exploratory factor analysis, and t-test was used to analyze the data. The study found that UK drug manufacturers consider bettering reliability and quality and reducing logistics costs as the most significant reasons for outsourcing logistics services. Furthermore, it was also found that a direct positive relationship between the service provider's techno-commercial offering and delivery performance, the possibility of being selected to offer these activities in the UK pharmaceutical manufacturing industry. The study's findings can be used to guide outsourcing decision makers like managers about the selection of Logistics service providers (Ali *et al.* 2023).

2.2.3 Processes of Outsourcing

According to Zhu (2017), logistics outsourcing has been adopted broadly by manufacturing firms as a means to drop costs and increase flexibility. In order to achieve these outcomes, logistics outsourcing processed must be managed through relevant governance mechanisms. The study aimed at shedding light on the effects of outsourcing management process (OMP), that is an operational mechanism on the following two types of logistics' services:

- Basics outsourcing
- Advance outsourcing

A survey data collection was conducted from two hundred and fifty subsidies of publicly listed manufactures in China. This was done after drawing of resource-based views, and then validation of the proposed model was based on the subsidies listed in China. Results announced that OMP affected the effectiveness of the two types of logistics outsourcing in a different manner each (Zhu *et al.* 2017).

On the other hand, basic logistics outsourcing affected cost and delivery precisely, advance logistics outsourcing influenced the performances along interaction with OMP (Zhu *et al.* 2017). It is also important to note that Zhu's (2017) study was the first study to report this relationship. Furthermore, his study contributed by showing the conditional utility of OMP and its service-dependent nature. This literature will be so

useful in trying to solve the problem currently faced by AB Ltd because there is a relationship between the types of industries, all the firms that were used to collect data were manufacturing firms like AB Ltd. Secondly, at the moment there is no proper OMP at AB Ltd, at the end of the research the possibilities of recommending an implementation for one are very high. Below in figure 2 is the conceptual model during the development of the hypotheses:

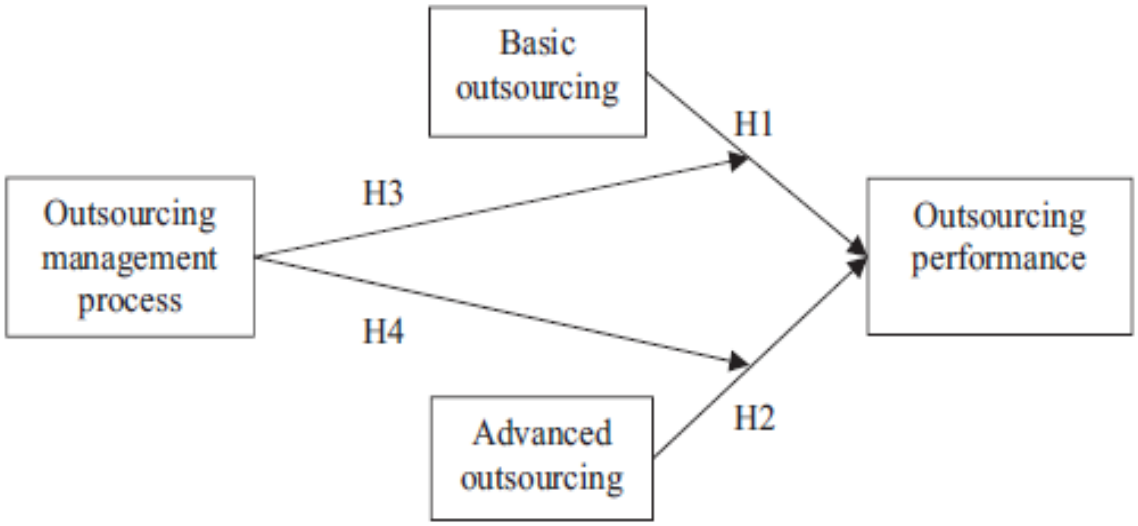


Figure 2-2 Conceptual model

Source: (Mazzola, Bruccoleri and Perrone 2019)

2.2.4 Effects of Outsourcing

Firms commit on variety of supply chain initiatives to improve their performance. Of particular interest to many practitioners and academics are the mixed outcomes that result from implementation of what is commonly viewed as a best practice. In a previous study, one popular practice called production outsourcing was studied with effects on the firm's overall operational performance. The study also looked at its manufactured components as well as customer loyalty. An analysis was completed on

secondary data across a wide variety of industries using data from a survey of manufacturing plant managers. Attention was drawn on resource-based view of the firm together with the supply chain and quality management literature to help in forecasting the operational performance to be expected when outsourcing production.

The analysis discovered that production outsourcing has deleterious effects on operational performance, with significant reductions in operating equipment effectiveness and on-time delivery. The study `also found that production outsourcing has a negative influence on customer loyalty when conciliated through operational performance. This research also makes methodological contributions in the development of robust measures of operational performance and related variables (Kenyon, Meixell and Westfall 2016). In the same breath this study found that firms that have practiced production outsourcing activities faced a reduction in manufacturing cycle times and a moderate increase in customer order led times (Kenyon, Meixell and Westfall 2016).

McCarthy, Anagnostou and Broedner's (2004) findings from a study showed similar results, the results suggested that either the management team making the outsourcing decision does not entirely understand the value and sustainability of the outsourced activities. Study also suggest that other organizational reasons are driving the outsourcing decisions. Some of the organizational reasons include the need to maintain a relationship with supplier due to changes on demand, shift towards new product and in some instances environmental reasons in the marketplace (McCarthy and Anagnostou 2004). To the effect of lower operational performance, this study also found that firms that decide to outsource some portion of their activities on production lost customers. This led to customer retention to be reduced thus resulting in additional expense to replace those defecting customers, which eventually erodes profit, and drive the firm to be less competent. However, this study does not stipulate if the rail industry (for example AB Ltd) is affected or not, therefore a need to continue with another study is essential.

Another study investigated the outsourcing versus insourcing decision for a manufacturer, facing carbon emission-sensitive demand and price, and an environmental regulation in the form of a carbon tax. The carbon emission considered was emission generated during the production phase. Among manufacturer and supplier, revenue sharing and cost sharing contracts, the outcomes were investigated. In case of outsourcing, the transportation emissions, were also considered. The impacts of customer's environment awareness, carbon tax, market potential, price sensitivity and supplier location on the outsourcing vs. insourcing decision, the environmental performance and the selling price, were studied. The results revealed that a higher customer's environmental awareness, a larger market potential and a longer distance among supplier and the manufacturers favor insourcing than outsourcing, although a higher carbon tax and a higher price sensitivity favor outsourcing. Whereas the insourcing versus outsourcing decision has been commonly modeled and studied in the literature. There were a few works fused into environmental considerations as well the contract arrangements into the decision, then investigated their impacts on the firm's strategy (Kandil, Hammami and Battaïa 2022)

2.2.5 Benefits of Outsourcing

Previous studies outline that in general, outsourcing enables organizations to become more flexible in setting production to variations in market demand and unpredictable changes. The study also suggests that outsourcing provides organizations with a number of technical, economic and strategic befits such as reducing information technology (Craig, Lacity and Willcocks 2014). Also, operation costs, by providing organizations with competitive advantages and improving technical competence finds a positive correlation between outsourcing ad overall deliverables (Magagula 2017).

Below are some the advantages of outsourcing:

- Low cost
- Risk management and continuity

- Quicker and improved services
- Access to advanced resource skills
- Main object activity specialized to ensure increased profit
- Flexibility in order fulfill the service needs

Freight trip generation (FTG) studies from before have made no contrast between insourced and outsourced variants of trips and the linked selection of truck types, despite the improvement in the logistics choices. Lack of FTG data disregarded by logistics outsourcing and the type of truck decisions have customarily neglected the ability of previous studies to untangle the complex exchange between freight trip frequencies and offer insights. The different truck types studied were low duty vehicle (LDV), medium duty vehicle (MDV) and heavy duty vehicles (HDV). Without the explicit considerations in the FTG meddling exercise, the travel decisions by logistics service choice (outsourcing vs. outsourcing) and different truck types (HDV vs MDV vs LDV) can be practiced due to common factors. The paper addressed the literature gap by collecting establishment based freight survey data. It then analyzed the trips on 6 different freight categories named below:

- Insourced LDV trips
- Insourced MDV trips
- Insourced HDV trips
- Outsourced LDV trips
- Outsourced MDV trips
- Outsourced HDV trips

The study’s findings acknowledge the presence of complementary and substitution effects between freight trip decisions as well as additional calculation responsibility resulting from the simultaneous model estimation. It appeared to be justified for bettering the logistical foundations of FTG models (Pani, Mishra and Sahu 2022).

2.2.6 Risks and Control of Outsourcing

The control and risks over outsourcing are a great concern to vendors as well and the client. Even though impact of control performance is known and was studied in the past, client and vendor relationship control-performance have not been combined into one unit. After data was collected from two hundred and thirty-four business process outsourcing projects by using paired quantitative strategy, it was shown that outcome control is more effective than process control (Liu, Wang and Huang 2017). The capability risk of client and vendor act as neutralizing roles on the effect of outcome control and process control as far as performance is concerned. When the effectiveness of outcome control is low, the effect of process control on performance is at its peak, all this occurs in the presence of high vendor capability risk. In other words, high effectiveness of outcome control is a result of high client capability risk but low effectiveness of process control (Liu, Wang and Huang 2017).

It is visible that various attributes generate different levels of performance under different control modes. In regard to control, either client or vendor capability risk play a role of a dual edge sword. In managing outsourced projects, enforcing control for both client and vendor for a risky situation should be always considered (Liu, Wang and Huang 2017).The results illustrated on Figure 2-3 show that the outcome control is more effective than process control in an outsourcing situation despite the fact that both formal modes affect the performance of BPO projects positively. Furthermore, the results suggest various control modes have different elements and also generate different performance levels.

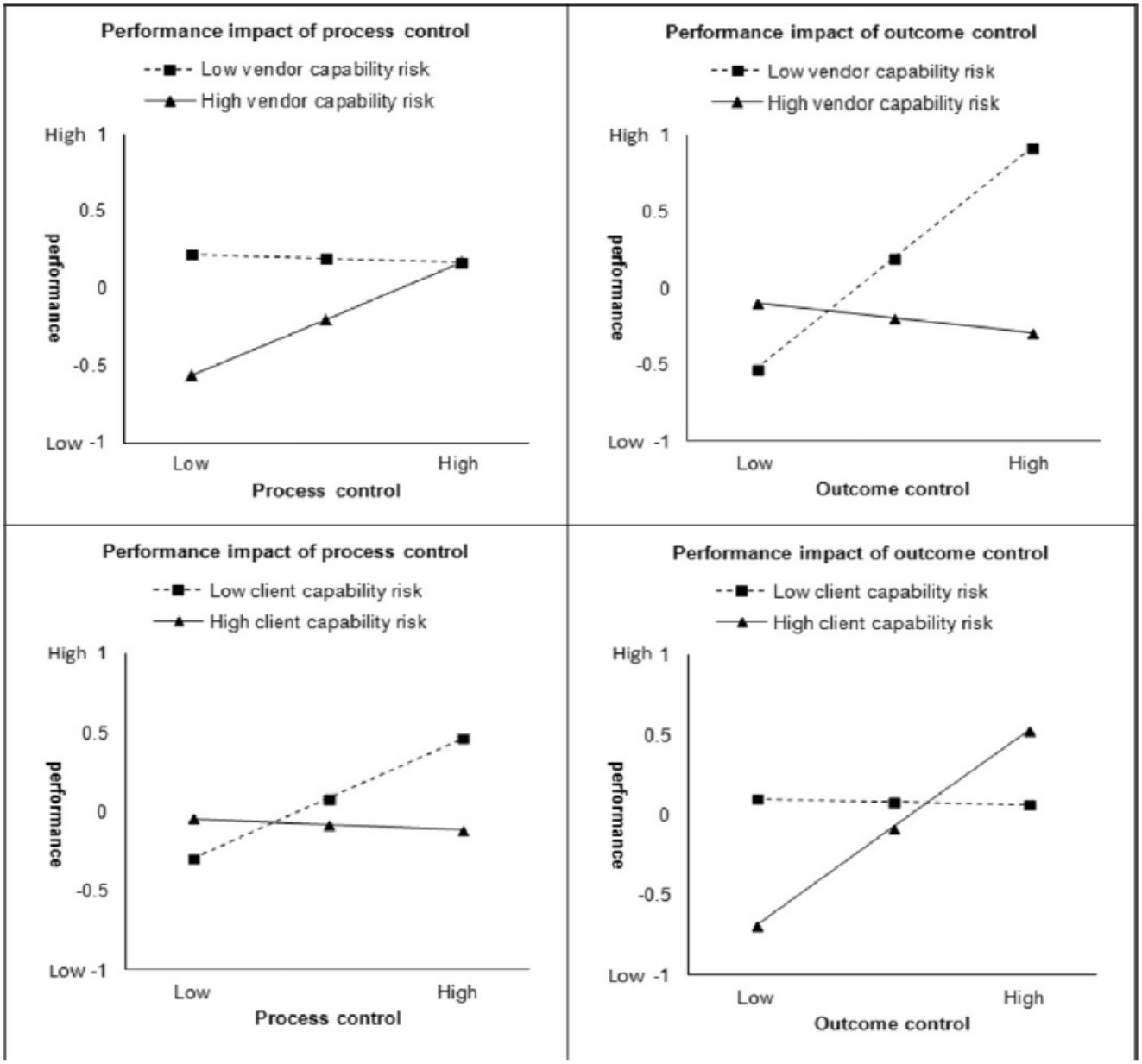


Figure 2-3 Interaction graphs

Source: (Liu, Wang and Huang 2017)

2.3 Production Approach

A need to elaborate on the production theory was essential for the study since outsourcing revolves around it. Theory of production refers to the study of production and the economic process of producing outputs from the inputs. During the process, resources are used by production to make goods and services that are best for use or

exchange in the market economy. Across the globe, some economists define production as the entire economic activity other than consumption. The final purchase is the only activity they do not see a commercial activity on. Production also uses resources that include manufacturing, storage, shipping and packaging (Shekhat 2016).

Shekhat (2016) defines a production process as a process that takes place over time and space, a flow concept. It is measured as a rate of output per period and there are three conditions to production processes namely:

- Form of the good ad service created
- Quantity of the good or service produced
- Temporal ad spatial distribution of the good or service produced

It's important to also define a production process; Shekat (2016) further states it is defined as any activity that boosts similarity between the patter of demand for goods and service, as well the quantity, shape, form, size length and distribution of all the goods and services available to the marketplace. Production is a process of bringing together different material inputs and immaterial inputs in order to produce something for consumption (output). What has value and contributes to the utility of individuals is the act of creating output, and a good or service.

2.3.1 Production Functions

Firms use the production function to establish what mixture of inputs they should use to produce, give price of capital and labor. They also used production function to establish how much output they should produce to give the price of a good. There is more production function named below from (Shekat 2016) study:

- Production function relates physical output of a production process to physical input or factors of production in economics.

- It also plays a mathematical function that describes the maximum amount of output that can be gained from a given number of inputs, which are usually labor and capital.
- The boundary and edge representing the limit of output that is gained from each possible mixture of inputs is described by the production function.
- Marginal costs that are increasing ca identified u utilizing production function.

2.3.2 Classifications of Production Systems

Production system refers to a set-up of the organization that is committed in producing products. It is a function in which resources are organized and converted into a product, where a process facilitates adding value to that product. There is four production system classification, and are discussed below.

- Job-Shop Production

Job-shop production are categorized by manufacturing one or few qualities of products. These products designed and produced as per the specification of customers within time and cost that is fixed prior. What makes this type of production unique is its low volume ad high variety of products produced. Since job-shop production requires general purpose machines and facilities, a variety of products ca e produced which makes this one of the advantages of it. Another advantage is that operators will become extra skilled ad trained due to that each job gives them an opportunity to learn (Mahmoud 2015).

- Batch Production

Batch production is defined by America Production and Inventory Control Society (APICS) as a form of manufacturing in which the job passes through various fictional departments in lots and batches. Each lot and batch may have a unique routing. This type of production is characterized by the manufacture of narrow number of products typically produced at intervals ad stocked awaiting to be sold to customers (Mahmoud 2015). There are some advantages that are associated with batch production, which

include, better utilization of plant and machinery, lower cost per unit, lower investment in machinery, plant, and promotion of functional specialization. Although advantages exist, there is complex material handling due to irregular and longer lead-time parts that flow in the shop. Production planning and control is also complex in this type of production, which is considered as a limitation together with the complex material handling. Furthermore, batch production is associated with some of the below characteristics:

- Flexible plant and machinery.
- Production runs that are shorter.
- Cost and manufacturing lead-time are lower as compared to job order production.

- Mass Production

This is the manufacturing of discrete components or assemblies using continuous process. Large volumes of production outputs justify this type of production system. The manner in which machines are arranged also unique from other production systems, they are in a line or product layout. Process ad product standardization if found here, and all its output follow the same path. Furthermore, mass production also has its ow characteristics that include shorter cycle times, lager volumes of products, lower in process inventory, perfectly balanced production lines, standardization of product and process sequence. Advantages for using mass production include higher rate of production with reduced cycle time, higher capacity utilization due to line balancing, less skilled operators are required, low process inventory and manufacturing cost per unit is low (Mahmoud 2015).

Limitations are also found in this production system and are as follows:

- Investments are high in production facilities.
- The longest operation determines the cycle time.
- Major changes required to line layout due to changes I product design.
- An entire production line will be stopped due to breakdown of one machine.

- Continuous Production

This type of production also found in AB Ltd manufacturing facilities, production facilities here are arranged as per sequence of production operations from the first operation to the final product. Material handling devices such as conveyers, transfer devices are used in order to allow the flow of items through the sequence of operations. Advantages of using this production system include having higher rates of production with reduced cycle times, standardization of product and process sequence, manpower is not required for material handling as it is completely automatic. The unit cost is lower due to due to high volumes of production, higher capacity utilization due to lie balancing, and person with limited skills can be used on production line. Continuous production can also be characterized by the following:

- Planning and scheduling are a routine action.
- Material handling function is automated fully.
- Parts and components are not identified with final product.
- Plant and equipment have no flexibility at all.
- Sequence of operations follows a predetermined process.

The relationship between production volume and product variety is displayed on the figure below. It is clearly visible that when production volume is high, there is less product variety realized and when the variety is high there is less production volume. Figure 2-4 reflects the classification of production systems that have been explained in detail on above paragraphs.

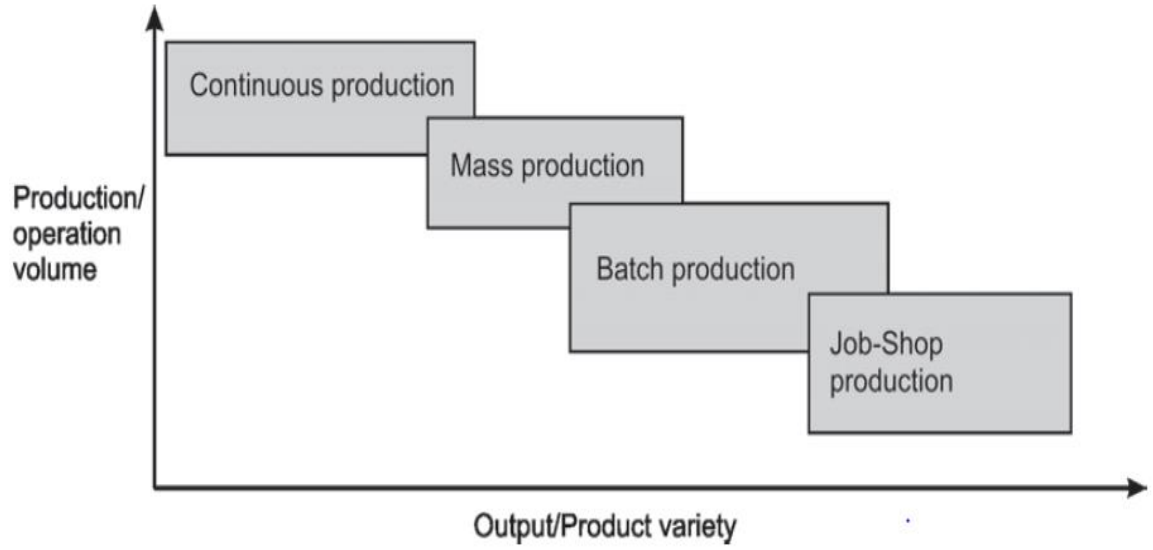


Figure 2-4 Classification of production system

Source: (Mahmoud 2015)

- Production Planning and Control

PPC systems are utilized to organize operating materials in a firm. PPC systems are software systems used to plan and schedule manufacturing resources such as personnel allocation and machinery. Requirements of these systems are subject to change sue to various types of drivers and currently affected by digitalization as well Cloud Manufacturing (CM) program. The study further states PPC systems consists of several modules listed below:

- Data base
- Knowledge base
- Modules that generate plans and schedule
- User interface

Study further states that there are some requirements that should be fulfilled by the system, during implementation of such systems. Database needs to accurate, consistent and complete. The planning the has access to the entire information

necessary for an optimal plan. Data basis newly developed systems depend on object orientated implementations. Information on available resources, their abilities with operations, material and resource consumption is provided by the database. The difference between dynamic and static planning data of a PPC system can be distinguished.

The first data is the input to the system in most cases. The number of products, due date, processing costriats and priorities is some of the data included. Data that is mostsly depended on the plan and optimization is summarized as “dyanamic date”. Example include idle time of machines, job tardiess and start and end time. PPC systems are issued with a knowledge-base that provide rules for a unique type of situation.

The knowledgebase is accessed by the planning module. Planning algorithms can also be different in their basic structure. During implementation of a PPC system, some with interactions with the user are noted and are of importance. This is when visualization of solutions needs to be taken into account. These are dispatch-lists ad input-output diagrams, Gantt charts, there are also many more. At times, schedule challenge is formulated as mathematical problem. This is when an objective has to be minimized. The suitable description and algorithm for solving this problem is additional exercise that is not covered on the study thus making it a gap.

2.4 Production Efficiency

Since the study is about the effectiveness of production outsourcing, it was essential to define and highlight how efficiency is measured. Production efficiency means producing the maximum quantity of output possible with a given set of inputs. The study also notes that production frontier is just the maximum output possible for each mixture of inputs. Companies that produce on frontier are regarded as efficient and companies inside the frontier are inefficient.

This study investigated the outsourcing versus insourcing decision for a manufacturer, facing carbon emission-sensitive demand and price, and an environmental regulation

in the form of a carbon tax. The carbon emission considered was emission generated during the production phase. Among manufacturer and supplier, revenue sharing and cost sharing contracts, the outcomes were investigated. In case of outsourcing, the transportation emissions, were also considered. The impacts of customer's environment awareness, carbon tax, market potential, price sensitivity and supplier location on the outsourcing vs. insourcing decision, the environmental performance and the selling price, were studied. The results reveled that a higher customer's environmental awareness, a larger market potential and a longer distance among supplier and the manufacturers favor insourcing than outsourcing, although a higher carbon tax and a higher price sensitivity favor outsourcing. Whereas the insourcing versus outsourcing decision has been commonly modeled and studies in the literature. There were a few works fused into environmental considerations as well the contract arrangements into the decision, then investigated their impacts on the firm's strategy (Kandil, Hammami and Battaïa 2022).

2.4.1 Measuring Efficiency

The measure of efficiency can be illustrated by considering an industry which uses a single input, at most one-unit output is produced as a result of converting one unit of the input. There is also what is called technical efficiency, this is simply the ratio of quantity an efficient company could have used to produce a unit of output to the quantity used by the company being evaluated. If a firm does not operate at the optimal scale or by making poor use of input scales, they can be considered inefficient. According to Burki and Terrell (1998) there are also two additional measures of efficiency sources used to determine source of inefficiency below:

- Scale efficiency - measures the output loss due to operating at inefficient scale.
- Pure technical efficiency – measures efficiency at the firm's current scale.

2.4.2 Manufacturing Productivity

Although manufacturing productivity also known as measurement of value added per hour, considerably varies from country to country, on average, manufacturing productivity is higher in United State (US) operations compared to Japanese and European operation (Baily, Bosworth and Doshi 2020) . The gap that is identified however is why there is so much international productivity variation. This study explored international productivity differences in manufacturing sectors across Japan, Germany and US. An extension and a reinforcement of the industry of origin method was developed. The method was to provide the new measures of productivity in nine industries that are located in the three counties mentioned earlier. The different industries are automobiles, beer, food, automotive parts, metalworking, steel, consumer electronics, soap and detergent. The study looked at two levels of explanation, which are production process level that focuses on the variation between capital, technology and skills. The second level the study looked at was why managers would opt to operate in different ways for different environment. How managers change production processes.

The study notes that relative factor process among the three countries is not consistent. The gap was among the labour productivity and observed variation on manufacturing design. The way functions and activities are arranged did not seem to be driven by relative price comparison. Furthermore, study notes that when companies based in certain country and set up operations in another country, they usually adapt with them the productivity level and production process of their home country. Based on this factor, it is evident that managers do not only react to price factor differences but to company policy factors (Naicker 2017).

2.5 Manufacturing

Manufacturing is defined as the industry or business of producing goods in large quantities in factories (dictionary 2020) (Oxford: 2020). This description then insinuates the idea that the manufacturing of such goods can either be manufactured by hands or by machines and upon completion, they are sold to customers

(Chryssolouris 2008). This asserts that there is a need for a reduced development time, thus a proper manufacturing process has to be followed which begins with a product design. (Walker 1993), in discussing the history of manufacturing, outlines that in the past, an artisan with assistants carried out the whole process of manufacturing. Walker (1993) further mentions that most manufacturing occurred rural backgrounds where household manufacturing served as a main manufacturing source. This was visible in the case of agricultural homesteads where in some cases, these homesteads were organized to form an organization or group-like production, something that still currently occurs in today's modern days.

Walker (1993) states that the first factory system was adopted in Britain in the late 18th century, a time characterized as the beginning of the industrial revolution. This then was spread across the world. Walker (1993) goes on to explain that the main characteristic of this era was the use of machinery, which was firstly powered by water or steam and later powered by electricity. This then continued to the introduction of mechanized assembly line where the assembling of parts in a repeatable fashion took place, where individual workers performed different specific steps for the product finalization. Introduction of machinery in the process of manufacturing yielded results of increased efficiency and lowering the cost of production (Westkamper 2007). Further from this process, automation was introduced, which further decreased the need for humans in the process of production, as there was a trend that accelerated the development of computer usage. This is also the issue in the case of developments at Transnet, overtime, with the change of things in the world and adaptability to modern ever-changing times.

In manufacturing, innovation is essential since it is the core driving force for continuously providing the customers with the best product. It also helps in keeping the products of the manufacturing industry completive. Around the world, the loss of a wide scale of low skilled jobs in manufacturing is a reality for a dozens of regions globally (G. Chryssolouris 2006). The study proceeds to note that this is due to two main causes which are industrial automation and production outsourcing. Training high level personal for new manufacturing jobs remains a challenge for education

stakeholders, hence providing means in needed in order balance the loss. Value creation stages for manufacturing industry are three:

- Pre-production
- Production
- Post-production

Figure 2-5 shoes manufacturing industry value creation stages that have been explained in detail on above paragraphs.

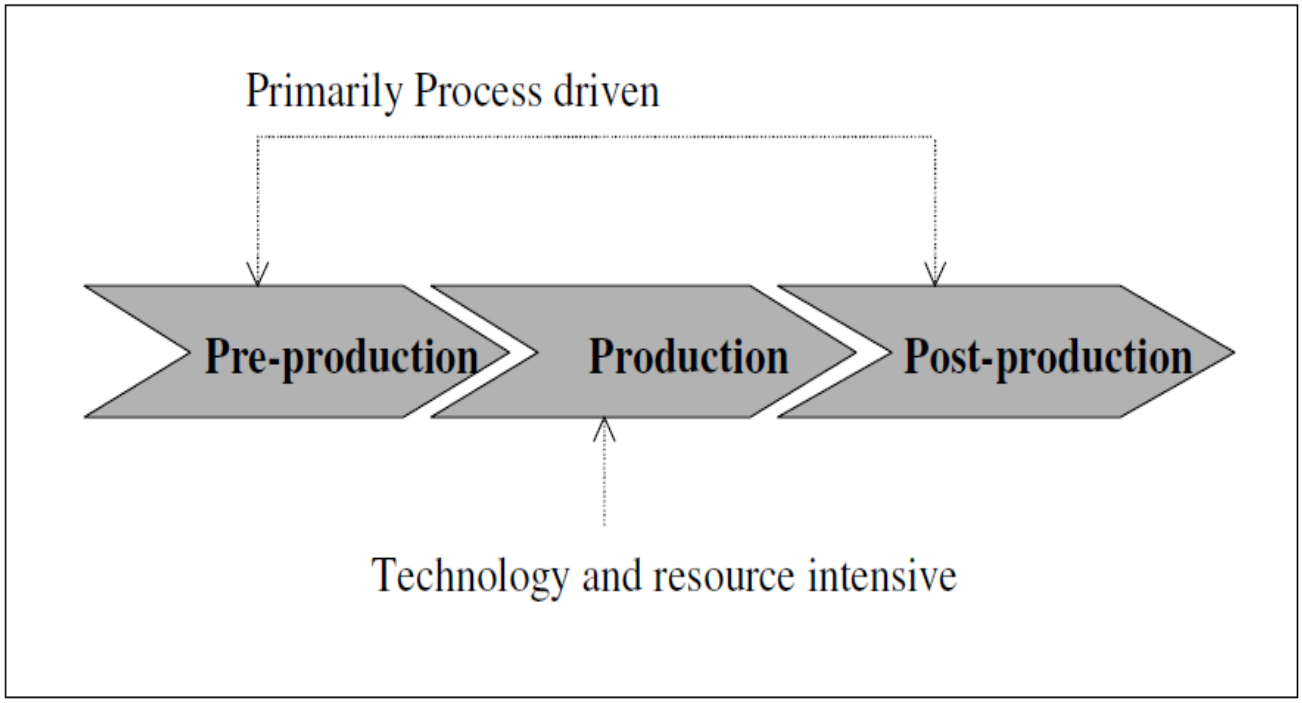


Figure 2-5 Manufacturing industry value creation stages

Source: (G. Chryssolouris 2006)

2.5.1 Manufacturing Processes

As mentioned above, there is a need for a reduction in the time that is spent in the process of manufacturing (Chryssolouris 2006) . Manufacturing process is defined as the process or the steps through which raw resources are transformed into a product,

a final useable product (Yin 2016). He further explains that this process has to ensure there is an improvement in the quality of the product being manufactured, reduction in the costs involved, an increased level of efficiency, a reduction in the consumption of energy as well as it being environmentally friendly. “The core of the operation of the manufacturing process is evolution and flow”, essentially, logistics and manufacturing are a jointly process. Concisely, there is no manufacturing of products without taking into account the logistics involved; the ongoing cycle of goods and services, hence there is no study of logistics without going through manufacturing.

The study highlights that this process has to include a specification of the technologies and methods used to detail how products ought to be manufactured. A detailed and informed manufacturing plan assists in exploring other options of the structure of the production line, which are obviously interested in goals such as making efficient assembly lines keeping in mind the aim of reducing time taken to manufacture products in a lessened period of time. It goes on to mention that the manufacturing process should highlight the production process planning: a detailed entire manufacturing concept, workflow process resource planning; technology-aided machining which details the use of software to control machines in the process of production; as well as time and financial estimates coupled with quality assurance.

2.5.2 Manufacturing in South Africa

Bekithemba (2014) speaks about manufacturing in South Africa as well as its future. He states that manufacturing is of particular importance to any economy that seeks to grow. Growth has been of a challenge to industrialized countries in such a manner that not going through the industrialization process would not allow the countries to achieve growth. It is further noted in his that, advancement in technology does allow countries to ounce some of the stages of the development phase; however, economy still requires developing the capabilities to maintain an acceptable employment base.

Among the diverse views and in some cases supported by insufficient facts on manufacturing sector of South Africa (SA), further study is needed to balance the

views about the sector. SA is a unique country, and some evidence suggests that it remains a priority if developing countries such as SA can merge with developing countries around the globe. The clear and evident structural break from apartheid to democracy in 1994 makes SA economy identifiable and unique. During apartheid era, the manufacturing industry was largely energy ad capital intensive, which was mainly dominated by six big conglomerates and State Owed Enterprises (SOEs). There was a decline in the manufacturing sector due to the huge unplanned and incoherent tariff policies, as well the apartheid's government's inability to diversify the sector.

Skills development for manufacturing sector is critical towards drawing positive attention from investors into the sector. Trade unions also play a huge essential role in offering direction on policies towards the development of skills. According to Bekithemba's (2014) study, trade unions like Congress of South African Trade Unions (COSATU) are primarily involved in the wage talks; their strategy has shown that their interest is towards the skills development. The Industrial Policy Action Plan (IPAP) must envisage allowing policies that will ensure that manufacturing today and in the future has a capacity to sustain huge industries. An important element to this would be creating effective demand in the economy. The study also states that government and business are missing the point in SA. This is because there is often a short-term view take about skills development in the country. The state cannot continue with job creation for unskilled labour, hence the country has to move unskilled labour up the value chain allowing it realize potential productivity gains. The sector in return will then be placed in a position that will allow it compete globally with China and become Africa's industrial powerhouse (Bekithemba 2014).

The fact that it has been highlighted that human capital is a key to growth; it is the result of several studies that have revealed the relationship between educational quality and economic growth. It is also clear that each year of schooling has been reported to increase long-term growth by 0.58 percentage points. When utilized effectively, skills contribute to the economic growth through road channels. Skills can also both increase employment levels and drive rise of productivity. An individual's employment opportunities are impacted by the skill, so an improvement of skill would

enable them to find a job easier due to skill demand (Chryssolouris, Mavrikios and Mourtzis 2013). Figure 2-5 illustrates the economic growth drivers that have been defined in detail above.

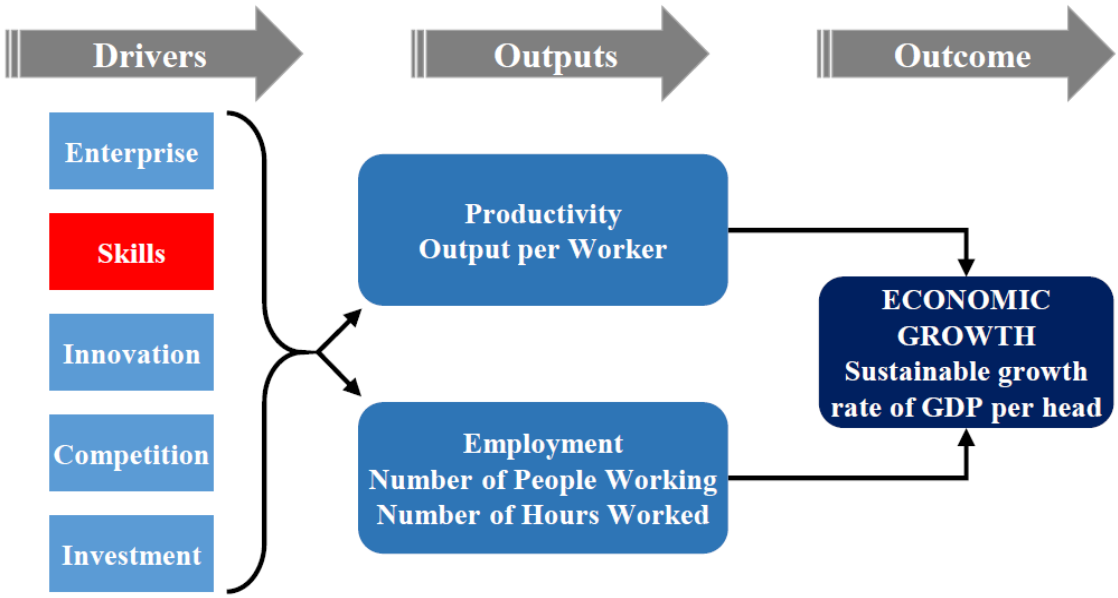


Figure 2-6 Economic growth drivers

Source: (Chryssolouris, Mavrikios and Mourtzis 2013)

South Africa does not have the market size in order to sustain huge scale manufacturing activities; however, location to the rest of Africa provides it with a promising opportunity to export with enough economies of scale. Another important aspect is automation; this will be important for creating capacity for competitive in the sector. South Africa has to take the Industrial Policy Action Plan (IPAP) towards transforming the manufacturing sector. IPAP has went through evolution and has improved compared to its original make, which also makes it a good example of effective coordination. IPAP is a unique and diverse program of action that aids trade and other tools deferential to industrial policy. The study stressed that SA must not

miss the opportunity to reindustrialize, based on evidence from America's economy which has reindustrialized over the last years.

One of the questions asked is will policy makers in South Africa be brave enough to taking steps towards the transformation of its economy. SA cannot continue to go down the same road again and policy makers have to act ad do what needs to be done in the interest of the country's future. Government has to embark on a long-term view taking into consideration its goal and objectives with respect to the manufacturing sector. Competitiveness is eventually what will be driving growth of the sector in the future. It will be crucial to direct objectives towards a more innovative sector. A complex understanding of the sector is necessary in order allow for additional coordination and intervention. This can be archived by much more coherent focus while tackling these issues (Bekithemba 2014).

It is assumed that outsourcing flexibility helps overcome financial challenges and administer evidence regarding the role of financial challenge and its interaction with operational flexibility on the possibility and market value of outsourcing. This study found that the likelihood of outsourcing is greater the higher the firm's financial challenges prior to outsourcing. Furthermore, the effect of financial challenge is higher the lesser the ex-ante operational flexibility, suggesting partial substitution between financial and operational flexibility. The study also shows that the market value impact of outsourcing announcements is predominantly positive confirming final flexibility gains positively with regards to ex-ante financial challenge. The study concluded that outsourcing is more of a vehicle to enhance flexibility and that financial challenges play an important role (Choi *et al.* 2021).

2.6 Conclusion

This chapter gives an overview of different types of outsourcing processes including the risks involved. The relevant literature was carefully selected in order give more understanding and background of the study. The chapter commenced with defining outsourcing, where different types of outsourcing processes and strategies was discussed including its risks. It extended to looking into production approach, where

production functions and classifications were broken down. This is where different types of productions systems are explained in detail as well.

The chapter also gives an overview of where South Africa (SA) stands as far as the manufacturing sector is concerned. During the investigation of the literature under manufacturing, South African economy was of big concern mainly due to the facts that SA is a developing country and had a structural break from apartheid to democracy in 1994. Some studies also noted that outsourcing might solve SA's problem, however not enough evidence could be provided by the studies to support the claims.

The study was conducted in rail manufacturing firm; therefore, it was essential to also elaborate on the different types of manufacturing processes. Since the study seeks to investigate if outsourcing can reduce operating costs, its influence on bottlenecks and increased demand, the chapter further gave some tools to measure production efficiency. This is where manufacturing productivity was also discussed.

3. CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter defined the research questions as well the bases of the research. The two objectives of the study, the format of the research tools and the establishment bases of the validity and reliability were reiterated. The research was conducted to evaluate the cost to outsource vs in-house production. Thereafter, an assessment of production outsourcing influence in the changing demand patterns and its influence on customer satisfaction was completed. The methodology chosen for this research was analytical, which followed a quantitative process that made it to be an applied type of research type. The chapter also highlights the research approach used to perform the research, research purpose, research design, target population, data collection techniques and as well as data analysis techniques.

3.2 Research Approach

As mentioned in chapter 1, there are two types of research approaches namely quantitative and qualitative approaches. Just to recap of what the study has already mentioned. The quantitative research basically deals with numbers and usually involves techniques for data analysis and statistical tools, whereas a qualitative research deals with words and emphasizes on non-statistical tools and techniques for data analysis (Castillo 2014). The study decisively used a quantitative method approach due to that both *(objective one and two*) analysis methods were statistical due to nature of data gathered which were historical data gathered from SAP system, as well as employee responses from an online survey.

- Historical data method was used by obtaining records of parts that are manufactured in-house, outsourced, as well procured externally from suppliers. Data analysis method was Chi-Square, which is classified under descriptive statistics methods was employed to analyze the variance in cost of outsourcing versus in-house production. A detailed justification will be provided later in the chapter.

- An online survey through questionnaires in statement form as per Likert scale theory was conducted (Carsten Ellwein 2020). The survey was completed by employees in different departments as well from various business units in the depot. Feedback was summarized after a Likert scale technique was used by the participants to mark the levels of agreement, where 1 is strongly disagree and 5 is strongly agree (Norman 2010). Analysis method used was hypothesis test, detailed justification will also be provided later in the chapter.

The need for employing two methods is that the study also has two objectives that required to be satisfied. It was best that each objective employs its unique data collection and analysis method to ensure that the research question and its sub-questions on the figure 3-1 below are answered accordingly.

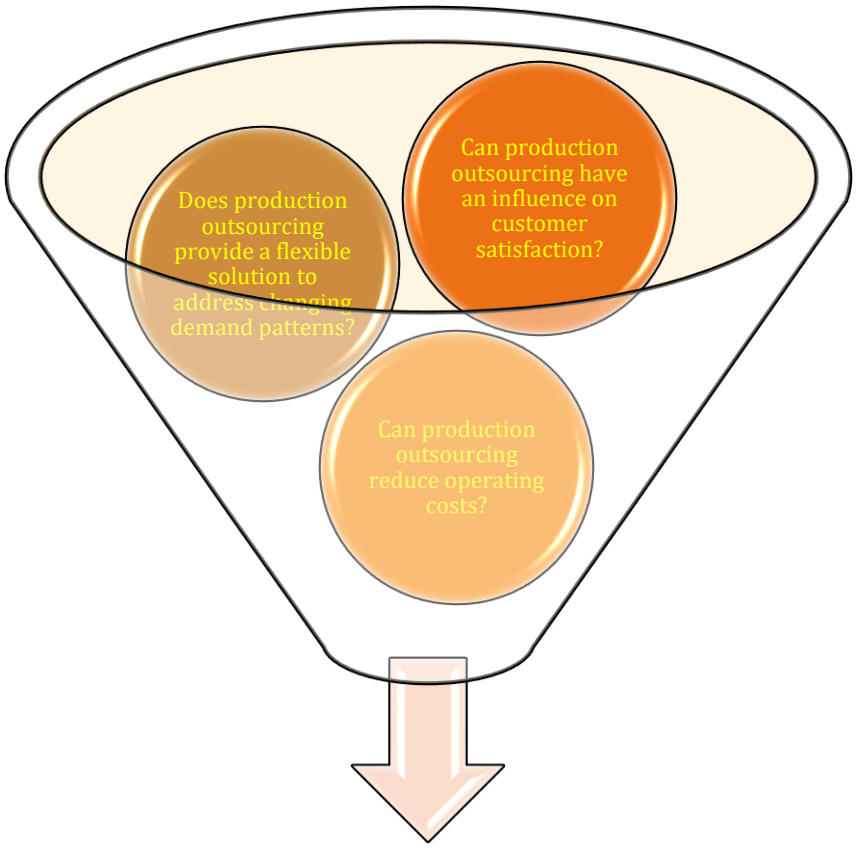


Figure 3-1 Main research question and sub-questions diagram

3.3 Research Purpose

The study has used exploratory purpose to determine the effectiveness of outsourcing at TE. The reason for this selection is that there are usually two purposes of research; it can be either explanatory or exploratory. A distinction on their characteristics exists between the two types. Explanatory purpose focuses on less-explained areas or unclear domains and dimensions for more knowledge. In exploratory research, the purpose is to explore less discovered and untapped area.

3.4 Research Design

The research design for the study selected was descriptive type of design. The reason for selecting this type of design is that from the survey and historical data collected, the study aimed to analyze and evaluate the cost to outsource production and cost to perform in-house production on the same parts. Furthermore, assess production outsourcing influence in changing demand patterns and its influence on customer satisfaction at TE Durban manufacturing plant.

The other types of designs that were not best suitable for the study include casual, correctional and experimental. Consequently, the study suits well with descriptive design because of the context to evaluate cost aspect amongst the variables. Following this design it was possible to collect data through both historical existing reports from SAP system and through survey.

A DMAIC (an abbreviation for Define, Measure, Analyze, Improve and Control) lean six sigma methodology was adopted in creating the framework below (Cheshmberah and Nabavi 2014) . It is to be noted that the study did not fully make use of the DMAIC in improving the current outsourcing and in-house production state at TE Durban however, it was partially employed. Below are the details of the DMAIC methodology.

***Define* -** In a number of occasions, TE Durban has been faced with risks of not meeting its monthly targets as well as producing products at a high cost. This was due to a various number of suspected reasons that include short supply of subcomponents to the production line due to machine breakdowns, longer process times, higher operating costs and longer raw material lead times from external suppliers

***Measure* -** Document analysis: Historical data of outsourced parts and assemblies was obtained from SAP system then exported to Microsoft excel using a laptop. An online survey questionnaire to get attitudes and opinions from employees about customer satisfaction and outsourcing response to increased demands was used. This was carried out by using 5-point Likert Scale technique to collect and gather responses using a laptop.

***Analyze* -** Data analysis method used was descriptive statistics analysis for ordinal data (Chi-Square) using both Microsoft excel and SPSS software for objective one. A hypothesis test method was again used for objective two; employed to analyze the data, using both Microsoft excel and SPSS software.

***Improve* –** Management to make use of the results analyses in order to recommend new ways of approaching any outsourcing decision in the company related to production.

***Control* -** Monthly review of statistical reports drawn from SAP system, and control charts to be used by management in order to monitor the effectiveness of the improved process implemented.

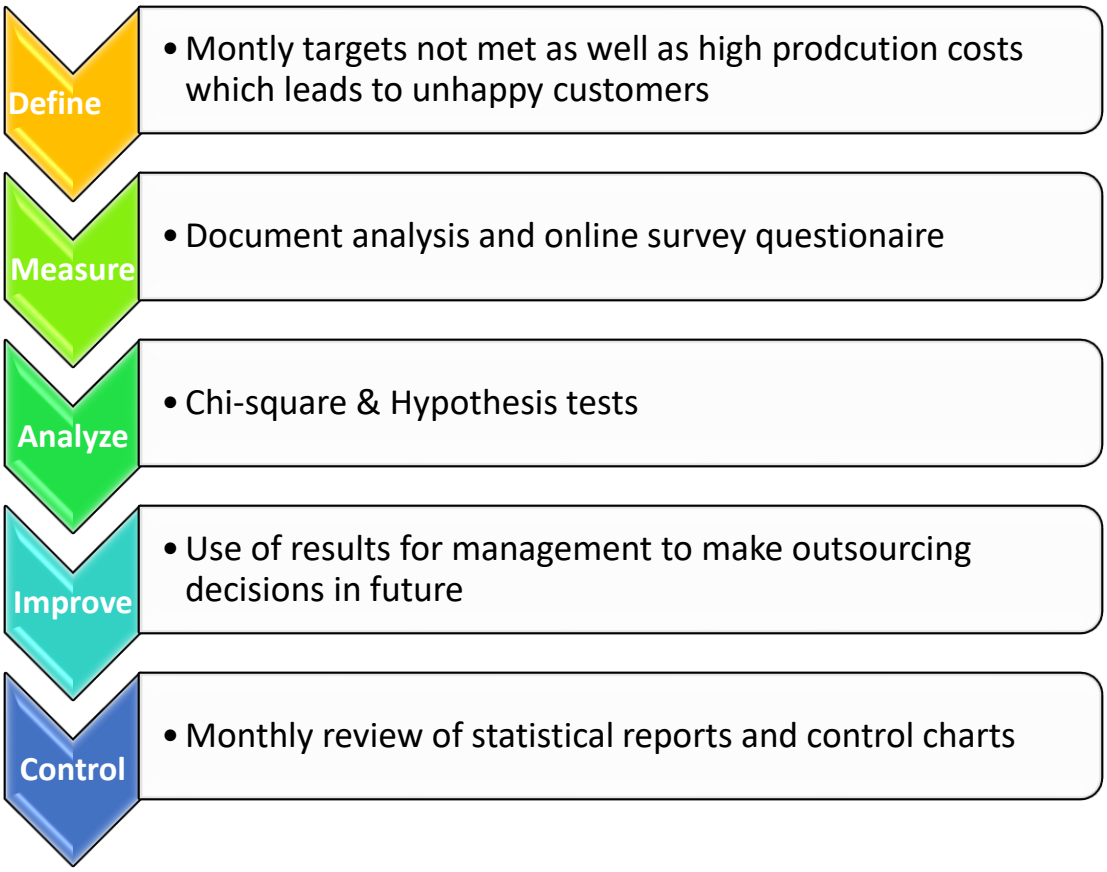


Figure 3-2 Methodology design flow diagram: DMAIC approach

3.5 Area of Study

The study was carried out at AB Ltd, KZN province, South Africa. The rationale behind this choice is from the sense that TE Durban manufacturing facility is the second biggest in the country with various types of manufacturing operations, compared to facilities located in Cape Town, Bloemfontein and Germiston. Hence the anticipated possibility of obtaining all necessary and relevant data from this facility was higher compared to the other manufacturing facilities.

3.6 Target Population

The study was conducted in six business units namely: locomotives, coaches, rolling stock equipment (RSE), wheels, wagons and ports. The study purposely selected the six business units in order to ensure that no business unit is omitted in the entire plant, in order to achieve accurate results and findings. The study focused on historical data from over a two-year period, from 1 January 2019 to 31 December 2020. A business unit is defined as a business that either manufactures or uses components, parts or raw materials to make a finished product and sub-products. These finished goods can be sold directly to customer AC Ltd and to other manufacturing businesses that use them for making a different product. Commonly outsourced items would be items that the businesses would prefer to buy externally instead of in-house. Since the study has more than one objective, the population where the survey was conducted was from employees that belong to the six business in all departments as well as from the rest of the manufacturing facility. So as long as the employees were AB Ltd employees, they were allowed to participate on the survey. Therefore, the selection criteria of the study were based on the above rationale.

Figure 3-3 Target population diagram

3.7 Sample Size and Technique

3.7.1 Sample Size

The sample size that was used for objective one was a total of 36 components drawn from 6 different types of businesses data base, namely: coaches, wagons, RSE, wheels, locomotives and ports. The sample size used in the study for objective two was 40 respondents from AB Ltd manufacturing facility.

3.7.2 Sampling Technique

The sampling technique is not the same as the sample. It is the procedure used to select the study participants and subjects (Fowler and Lapp 2019). The study looked at two sampling techniques to choose from: nonprobability and probability. The study then employed probability sampling. The reason for selecting this type of technique is

that all manufacturing components studies for objective one and employees which were respondents for objective two from AB Ltd manufacturing facility had an equal chance of being in the sample overall. Nonprobability method was not suitable for this kind of study due to that it is usually used when researcher has difficulties in locating participants, it is also regarded as weak form of sampling. Furthermore, for objective one, systematic sampling methods was used to obtain historical data from the enterprise resource planning system named SAP system. For objective two, simple random sampling was utilized to obtain opinions from AB Ltd staff about the effectiveness of production outsourcing in the organization.

3.8 Sources of Data

Primary data was used from historical information over a period of two years for objective one. Also, for objective two, primary data was collected using online questionnaire where AB Ltd staff used a Likert scale to indicate their opinions about the effectiveness of production outsourcing in the company.

3.9 Data collection Technique

As mentioned previously in this chapter that the study employed a quantitative method approach. The reason for this was the nature of the variables on the data collected for the first and the second objective which followed a quantitative approach. Some of the variables were unit cost to produce in-house, unit cost of parts that were outsourced, unit of measure per part, the date each process took place during this two-year period. Another reason is that a chi square statistical method was used as an analysis method for objective one which was to determine if outsourcing can actually reduce operation cost of the company. The study has two objectives with different collection techniques as well two different data analysis techniques. This therefore means that the second objective which was to determine influence of production outsourcing in managing and supporting increased customer demands followed a quantitative approach too. For this objective, statistics analysis hypothesis test was employed as analysis methods to responses received from the employees using survey in a form of questionnaire.

3.9.1 Data Collection Method for Objective One

In order to determine if production outsourcing can reduce operating costs, data was collected, historical data of the company to be precise. Historical method refers to the use of primary existing or historical data to answer a particular question. There can be various natures of data depending on the question being asked, such as newspaper articles, government records and demographic records etc. (Janet Toland 2011). The use of historical data poses several road questions such as:

- *Does the data suit the theoretical questions asked?*
- *What meaning does that data hold?*
- *Originally, how was the data collected?*

This study followed the below steps during the process:

Step 1

Login to enterprise resource planning (ERP) system utilized by AB Ltd called System Application Product (SAP) system.

Step 2

Draw a material movement history report by entering a transaction code for SAP transaction code.

Step 3

A date from 1 January 2019 to 31 December 2020, the specific business unit number or plant number was entered into the SAP system, the report was executed to run. This process was repeated 6 times since the study focused on all 6 business units in TE Durban main center manufacturing facility.

Step 4

After some minutes, the historical data about all material movements that took place between 1 January 2019 and 31 December 2020 was retrieved from the system. This was in a form of raw data because it included the below:

- Parts and finished goods sold
- Finished goods received and issued between internal business,
- Parts written off and parts written up
- All reversals that took place
- Outsourced parts received from external supplier,
- Insourced parts received from internal production into the warehouse
- Date, quantity, time, unit of measure, material number, material description
- Cost of parts, finished goods and assemblies

Step 5

The data from this report was then exported from SAP system to Microsoft excel for sorting. This is where unnecessary information that was not going to contribute to study was removed. After sorting the data, the below was the only data description required for objective one.

Table 3-1 Description and abbreviation table

Description	Abbreviation
Material no.	**MAT**
Material Description	**MD**
Business Unit	**BU**
Entry Date	**ED**
Unit of Measure	**UOM**
Outsource Cost (Rand)	**OC(R)**
Price Each	**PR**
Insource Cost (Rand)	**IC(R)**

Step 6

The last step was to consolidate the data from the six business units into one sheet. From the raw data, the parts had to have the below characteristics order to be found useful for the study:

- Have history of being produced in-house
- Have history of being outsourced as well produced in-house
- Parts have to be insourced and outsourced between 2019 and 2020 Period as mentioned in earlier discussions.

The selection of individual subsets of the population to make statistical inferences from them and roughly calculate characteristics of the whole population is called sampling technique. The probability sampling and non-probability sampling are two main two-border types of sampling techniques (Etikan 2017) .This study adapted a probability sampling technique, hence appendix 1 attached reflects the 42 items that were

sampled from six business units population worth of population, which will be analyzed later using Chi-Square test analysis method.

3.9.2 Data Collection Method for Objective Two

An online survey in a form of statements, in order to obtain attitudes and opinions of employees with regards to influence of production outsourcing on customer satisfaction as well as increased demands was used. A 5 point Likert scale technique was used, with 1 as strongly disagree and 5 as strongly agree (Norman 2010). Norman's study further defines Likert scale as a psychometric response scale mainly utilized in questionnaires in order to obtain the participants degree or preference of agreement with a statement or in some cases a set of statements. Likert scales are usually non-comparative scaling methods and are also one-dimensional in their form and nature. An ordinal scale allows respondents to indicate their level of agreement with a given statement. The study used the below 5-point scale with the below range:

1 = Strongly disagree

2 = Disagree

3 = Neither

4 = Agree

5 = Strongly agree

In some instances, a 4-scale is used to give responses that are forced measures, where there are no indifferent options available to choose from. Each specific question or item can have its own response analyzed individually and can also be summed up with other similar items to make a score for a set of statements. This is the main reason why Likert scales are sometimes called summative scales. Separate responses are usually treated as ordinal data due to that fact that although the response levels do have a relative position, one cannot presume that participants recognize the variation

between adjacent levels to be equal. Below are the 11 statements used for the survey during the research study in the Durban manufacturing plant:

Likert Scale Statements

Production outsourcing influence on customer satisfaction and increased demands:

1. *Production outsourcing is a good practice in general for the organization.*
2. *Customers are happy with quality of outsourced parts and assemblies.*
3. *There is benefits from production outsourcing.*
4. *It is better to outsource than to produce in-house.*
5. *Outsourcing is not expensive compared to in-sourcing.*
6. *Lead times are within desired time for outsourced components.*
7. *Management does not like to outsource unnecessary.*
8. *The organization should not stop outsourcing.*
9. *Outsourcing does not take away people's jobs in the organization.*
10. *When outsourcing is done, production targets are met.*
11. *Customers are happy all because of outsourcing at times.*

See Appendix 3 for summary of the scores.

3.10 Data Analysis Technique

Data analysis is a critical part in this research because it helped the researcher to conclude the results of the study. A chi-square test was used for each objective in order to answer the research question. For objective one, test for independence which compares two sets of categories which are sourcing type (insourced parts as well as outsourced) if they sourced at high or low costs. For objective two the same type of chi-square test was used to analyze survey responses gathered using questionnaire from TE employee, through a set of eleven statements.

Chi-square statistics is a nonparametric statistical technique that is used to determine whether a distribution of observed frequencies is different from the theoretical expected frequencies (M. Yousof *et al.* 2021). The data that is used in a chi-square has to satisfy the following conditions:

- Randomly drawn from population.
- Reported in raw counts of frequency.
- Measured variables must be independent.
- Observed frequencies cannot be too small.
- Values of independent and dependent variables must be mutually exclusive.

There are two types of chi-square tests namely: Test for goodness of fitness which compares the expected and observed values to determine how well an experimenter's predictions fits the data. The second one is the test for independence which compares two sets of categories which are high or low costs to outsource and insource for this study. Therefore, the goodness of fitness test was not selected because it focuses only on expected and observed frequencies. After comparison of the two sets of data, the test for independence determined whether the two groups were distributed differently within the categories (Shen, Panda and Vogelstein 2021).

3.10.1 Data Analysis Procedure for Objective One

Since the study selected chi-square test for independence, it considered the cost of the parts under various conditions. Categorical variables: sourcing type (two levels: insource vs outsource) and cost degree (two levels: High vs Low). The statistical question that the study wanted the answer to was whether the sourcing cost is related to the sourcing type in the organization. In other words, the study wanted to know if in-house production cost differs from outsourcing costs by categorizing the costs into high or low.

To answer this question, the study started off by putting data into *contingency table.* At this stage, the table only showed observed frequency data, there after the table was used to calculate the *expected* frequencies*.*

Table 3-2 Observed frequency table

	Insource Cost	**Outsource Cost**
High	A	B
Low	C	D

At this stage, one would have an idea when looking at observed frequencies weather the cost is different between the sourcing types. However, to test whether the observed difference is significant, a chi-square test outcome would indicate that. This means that the aim would be to see if the rate of the cost observed frequencies is significantly different from the cost rate of frequencies that would be expected to be seen by chance. This clearly means that what would be expected to be seen if there was “no relationship” between the two variables in question? For this study, no relationship would mean that the cost rate of insourced parts was no different to that of outsourced parts. This can be expressed by null hypothesis and alternative hypothesis. Null is a particular claim concerning how particular data is distributed, alternative hypothesis disagrees with the claim (Kenyon, Meixell and Westfall 2016). The null and alternative hypothesis for Chi-Square test for goodness of fitness is stated as:

H_0 - Null Hypothesis

H_1 - Alternative Hypothesis

The null and alternative hypothesis for the study for objective one is stated as:

H_0 : The cost rate of insourced parts is not different to that of outsourced parts.

H_1 : The cost rate of insourced parts differs to that of outsourced parts.

Step 1

Add numbers across columns and rows, then calculate total number in chat. A, B, C & D represent numbers.

	Insource Cost	**Outsource Cost**	**Total**
High	A	B	**AB**
Low	C	D	**CD**
	AC	**BD**	**ABCD**

Step 2

Calculate expected numbers for each individual cell (i.e. the frequencies we would expect to obtain if there were no association between the two variables). This is achieved by multiplying row sum by column sum and dividing by the total number.

$$\text{Expected Frequency} = \frac{\text{Row Total x Column Total}}{\text{Grand Total}}$$

Using the first cell of the table (Insource/High);

$\frac{AB \times AC}{} = \mathbf{E}$

ABCD

$\frac{CD \times AC}{ABCD} = \mathbf{E}$

$\frac{AB \times BD}{ABCD} = \mathbf{F}$

$\frac{CD \times BD}{ABCD} = \mathbf{F}$

This needs to be done for each cell above as indicated.

Step 3

Now the observed number and expected number is available. The observed number is the number in the first chart. The expected number is the number in the last step (step 2). Redo the contingency table, this time adding in the expected frequencies in brackets below the obtained frequencies:

	Insource Cost	**Outsource Cost**	**Total**
High	A *(E)*	B *(E)*	**AB**
Low	C *(F)*	D *(F)*	**CD**
	AC	**BD**	**ABCD**

Step 4

Calculate Chi-square using the below formula:

$$\chi^2 = \Sigma \frac{(O-E)^2}{E} \quad \text{...or...} \quad \chi^2 = \text{Sum of } \frac{(\text{Observed - Expected})^2}{\text{Expected}}$$

X^2 - Chi-square value

O - Observed

E- Expected

Calculate this formula for each cell, one at a time. For example, cell #1 (Insource cost/High):

Observed number is: A

Expected number is: E

Calculate this formula for each cell, one at a time. Example provided for cell #1 (Insource cost/High):

Plugging this into a formula, one would have:

$$X^2 = \frac{(A-E)^2}{E}$$

X^2 = *Value 1*

Proceed to do the same to the rest of the cells.

Cell #2 (Outsource cost/High)

X^2 = *Value 2*

Cell #3 (Outsource cost/Low)

X^2 = *Value 3*

Cell #4 (Outsource cost/Low)

X^2 = *Value 4*

Value = *V*

Step 5

Add together all the final numbers for each cell obtained in step 4. Since there is a total number of four cells, four numbers should be added together like below in order to obtain a final Chi-square number.

V1+V2+V3+V4 = **Chi-square value**

Step 6

Calculate degrees of freedom (Justin Goodwin and Mirghani Ibnoaf 2006).

It's simply the number of categories minus one.

df = number of categories -1

Assessing the size of the obtained Chi-Square value, the following procedure needs to be followed:

(a) Work out how many degrees of freedom we have.
(b) Decide on probability level represented as (*p).*
(c) Find a table of critical Chi-Square values (*found in most statistics textbook*). This example shows *degrees of freedom(Justin Goodwin and Mirghani Ibnoaf) a*s 5, probability *level (p)* value as 0.05 (5%), the critical value can be

established as **11.07**. This therefore means that, in order to reject the null hypothesis, the final answer to the Chi Square be **greater or equal to 11.07**.

Degrees of Freedom	99%	95%	90%	70%	50%	30%	10%	5%	1%
1	0.00016	0.0039	0.016	0.15	0.46	1.07	2.71	3.84	6.64
2	0.020	0.10	0.21	0.71	1.39	2.41	4.60	5.99	9.21
3	0.12	0.35	0.58	1.42	2.37	3.67	6.25	7.82	11.34
4	0.30	0.71	1.06	2.20	3.36	4.88	7.78	9.49	13.28
5	0.55	1.14	1.61	3.00	4.35	6.06	9.24	11.07	15.09
6	0.87	1.64	2.20	3.83	5.35	7.23	10.65	12.59	16.81
7	1.24	2.17	2.83	4.67	6.35	8.38	12.02	14.07	18.48
8	1.65	2.73	3.49	5.53	7.34	9.52	13.36	15.51	20.09
9	2.09	3.33	4.17	6.39	8.34	10.66	14.68	16.92	21.67
10	2.56	3.94	4.86	7.27	9.34	11.78	15.99	18.31	23.21
11	3.05	4.58	5.58	8.15	10.34	12.90	17.28	19.68	24.73
12	3.57	5.23	6.30	9.03	11.34	14.01	18.55	21.03	26.22
13	4.11	5.89	7.04	9.93	12.34	15.12	19.81	22.36	27.69
14	4.66	6.57	7.79	10.82	12.34	16.22	21.06	23.69	29.14
15	5.23	7.26	8.55	11.72	14.34	17.32	22.31	25.00	30.58
16	5.81	7.96	9.31	12.62	15.34	18.42	23.54	26.30	32.00
17	6.41	8.67	10.09	13.53	16.34	19.51	24.77	27.59	33.41
18	7.00	9.39	10.87	14.44	17.34	20.60	25.99	28.87	34.81
19	7.63	10.12	11.65	15.35	18.34	21.69	27.20	30.14	36.19
20	8.26	10.85	12.44	16.27	19.34	22.78	28.41	31.41	37.57

Figure 3-4 Critical Chi-Square value table example (Aslam 2021)

(d) Establish the critical Chi-Square value and compare to the obtained value.

If the obtained Chi-Square value is greater than the one on the table, then the conclusion is that the obtained Chi-Square value is too large to have arisen by chance. This would then mean that two variables are likely to be related in some way or another. The Chi-Square test tells us that there is some relationship between the two variables in question. The null hypothesis is then rejected when the Chi-Square value is larger than one on the table.

On the other hand, if the obtained Chi-Square value is less than the one in the table, the conclusion is that there is no reason to think that the observed pattern of frequencies is not due to simply chance. This means that the null hypothesis cannot be rejected because the variables are unlikely to be associated.

It is important to note the assumptions of the Chi-Square test below, in order for the results to be reliable:

- The observations need to be independent; each subject must display one data point.
- Data are randomly sampled from the population about which inferences are to be made.
- Some problems arise when the expected frequencies are too small. The Chi-Square rule of thumb states that Chi-Square should not be used if more than 20% of the expected frequencies have a value of less than 5, regardless of what the observed frequencies are (Yousof *et al.* 2021).

3.10.2 Data Analysis Procedure for Objective Two

For object two, the study was to assess employees' perceptions on production outsourcing effectiveness in managing and keeping up with increased customers' demands. An online survey was completed using google forms by 40 participants from AB Ltd. An internet link was sent via email to the employees, they were requested to click the link and follow the instructions until from google forms until they complete the last question. Automatically the researcher received the responses on google forms as the employee's finish with the survey. The study established whether the employees responded positively or negatively to their experience and knowledge. A hypothesis test for dependent data was adopted in analyzing the data collected through a survey questionnaire. Hypothesis test is an act in statistics that takes place when an analyst tests an assumption in reference to a population parameter. Sample data is used to assess the credibility of hypothesis test. The nature of the data determines the methodology employed by the analyst (Khademi 2015).

This second objective was to address a question of "does production outsourcing has an influence in managing and keeping up with increased customer demands"? In order to address this question, the study proceeded to start off by establishing the null and alternative hypothesis, and was presented below:

H_0 : There is no difference between the means of the two samples of responses.

H_1 : There is a difference between the means of the two samples of responses.

Furthermore, the study categorized the four hundred and forty answers from the eleven survey questions. As mentioned earlier in the study that a Likert scale of 1 to 5 was used to obtain the responses from the employees.

The table 3-3 below represents a more simplified manner in which strongly disagree and agree were classified as negative, neither classified as neutral, strongly agree and agree were combined and classified as positive. The reason for this was to make it simpler for the hypothesis t-test to be applied in order to obtain the most accurate results during the analysis process.

Table 3-3 Combined categorized 1-5 Likert scale responses

Category	
Positive	4&5
Neutral	3
Negative	1&2

The table 3-4 below is a summarized representation of the four hundred and forty answers, eleven questions answered by forty participants. This means that each participant answered about eleven questions and for each question, there were forty answers from all forty employees.

Table 3-4 Summarized responses from employees (*see Appendix 2*)

Statement	Positive	Neutral	Negative	Total
S1	#	#	#	40
S2	#	#	#	40
S3	#	#	#	40
S4	#	#	#	40
S5	#	#	#	40
S6	#	#	#	40
S7	#	#	#	40
S8	#	#	#	40
S9	#	#	#	40
S10	#	#	#	40
S11	#	#	#	40
Total	0	0	0	440

After a further consideration after data collection, the study decided to eliminate neutral responses because it did not want to force the employees that participated on the survey to choose sides (*agree or dis-agree*). Hence out of 40 respondents, 11 with neutral responses were eliminated and 29 was left for analyses. As mentioned earlier that the study also combined strongly disagree and agree, as well as strongly agree and agree. Below table 3-5 shows the final data that was analyzed in the following chapter 4 of the study.

Table 3-5 Summarized responses from employees, with neutral excluded

	Agree	*Disagree*	
Statement	**Positive**	**Negative**	**Total**
S1	9	20	29
S2	12	14	26
S3	14	13	27
S4	7	25	32
S5	5	22	27
S6	14	16	30
S7	25	7	32
S8	14	17	31
S9	11	24	35
S10	14	11	25
S11	9	18	27
			29

The study created questions that when combined, measured a particular trait which in this case is the perceptions around production outsourcing in AB Ltd. The study does not have unique and stand-alone questions. The table below shows the different types of data analysis procedures for Likert scale data

Table 3-6 Data analysis procedures for Likert scale data (Aslam 2021)

Suggested Data Analysis Procedures for Likert-Type and Likert Scale Data		
	Likert-Type Data	**Likert Scale Data**
Central Tendency	Median or mode	Mean
Variability	Frequencies	Standard deviation
Associations	Kendall tau B or C	Pearson's r
Other Statistics	**Chi-square**	ANOVA, **t-test**, regression

In order to distinguish between tests of hypothesis for independent and dependent samples, the symbol for hypotheses with dependent samples was used. In this case positive and negative responses from the survey. For dependent sample hypotheses, the delta (δ) symbol was used, to symbolize the difference between the two samples.

This therefore means that in null hypothesis, we state that the difference of scores across the two measurement is equal to 0.

The following steps were followed in analyzing data for objective two:

Step 1 - State the null alternative hypotheses.

During the process of stating the null hypothesis, we assumed there is no difference between the means of the two independent samples. The sample was taken from forty employees. They had to respond to eleven questions each, in order for the study to be able to determine the effectiveness of the production outsourcing at TE Durban by computing the test statistics. This was determined through a survey questionnaire, where the results were simplified to that overall responses agree or disagree that production outsourcing is effective. The hypothesis test is that there is no difference between the means of the two samples and the alternative hypothesis is that the two means of the samples are not equal.

Therefore, the null hypothesis in this case would be:

H_0 : There is no difference between the means of the two samples of responses.

H_α : There is a difference between the means of the two samples responses.

$$H_0 : \mu_1 = \mu_2$$
$$H_a : \mu_1 \neq \mu_2$$

The table below indicates the format that the study focused on in presenting the two samples.

Table 3-7 Two independent samples

Statement	Agree	Disagree
S1	#	#
S2	#	#
S3	#	#
S4	#	#
S5	#	#
S6	#	#
S7	#	#
S8	#	#
S9	#	#
S10	#	#
S11	#	#

Step 2 - Choose significant level – α.

This is a two tailed test since there are two independent samples from the population that has a total of 11 questions asked with a summarized total of 22 responses from both categories of positive and negative. The *t* – distribution was used since the sample was little bit low. The degree of freedom was then calculated, with a 0.05 significance level.

Step 3 - Set the criteria (critical values) for rejecting the null hypothesis.

The critical value was then established by first establishing an alpha level using the *t* distribution table below, a full table available on appendix 5.

	Area in One Tail				
	0.100	0.050	0.025	0.010	0.005
	Area in Two Tails				
df	0.200	0.100	0.050	0.020	0.010
1	3.078	6.314	12.706	31.821	63.657
2	1.886	2.920	4.303	6.965	9.925
3	1.638	2.353	3.182	4.541	5.841
4	1.533	2.132	2.776	3.747	4.604
5	1.476	2.015	2.571	3.365	4.032
6	1.440	1.943	2.447	3.143	3.707
7	1.415	1.895	2.365	2.998	3.499
8	1.397	1.860	2.306	2.896	3.355
9	1.383	1.833	2.262	2.821	3.250
10	1.372	1.812	2.228	2.764	3.169
11	1.363	1.796	2.201	2.718	3.106
12	1.356	1.782	2.179	2.681	3.055
13	1.350	1.771	2.160	2.650	3.012
14	1.345	1.761	2.145	2.624	2.977
15	1.341	1.753	2.131	2.602	2.947
16	1.337	1.746	2.120	2.583	2.921

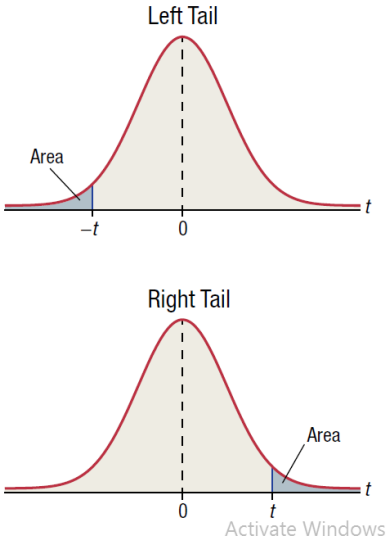


Figure 3-5 t distribution table (Lane 2019)

Step 4 – Compute the test.

The test statistics was calculated, but before it was calculated, a pooled estimate variance from the sample had to be found. When testing a hypothesis for two independent samples, we need to calculate the estimated standard error of the difference between the sample means first,

$$s_{\bar{x}_1-\bar{x}_2} = \sqrt{s^2\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}.$$

Where:

Sizes of the two samples are represented as below:

$$n_1 \text{ and } n_2$$

Pooled sample variance is represented below:

$$s^2$$

Calculated as follows:

$$s^2 = \frac{\sum(x_1 - \bar{x}_1)^2 + \sum(x_2 - \bar{x}_2)^2}{n_1 + n_2 - 2}$$

But the formula often expressed as below, simplified by substituting *SS* for the sum of squared deviations:

$$s^2 = \frac{SS_1 + SS_2}{n_1 + n_2 - 2}$$

At this step, data from the two groups is presented. Calculating the test statistic for independent samples is a bit different since the study deals with two sets of data. The below formula is used to calculate the test statistics:

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{s.e.(\bar{x}_1 - \bar{x}_2)}$$

Where:

$\bar{x}_1 - \bar{x}_2$ is the difference between the sample means

$\mu_1 - \mu_2$ is the difference between the hypothesized population means

$s.e.(\bar{x}_1 - \bar{x}_2)$ is the standard error of the difference between sample means

Step 5 - Make a decision, reject or fail to reject the null hypothesis.

When the *t* value is less than or equal to the significance level, we reject the null hypothesis. This means that the data favors the alternative hypothesis, the results would then be statistically significant. However, if the *t* value is greater than the

significance level, we fail to reject the null hypothesis and the results will not be significant.

Step 6 - Interpret the decision within the context of the problem.

The decision will depend on the *t* value obtained in step 5, it would be concluded that employees do not think production outsourcing is effective if the *t* value is equal or less than the signifcant level. However the *t* value if greater than the significance level, then that would mean that employees do think that production outsourcing is effcetive through yelding positve reults by managing and supporting increased demand.

3.11 Conclusion

The chapter addressed the methodology of the study, which was based on Define, Measure, Analyze, Implement and Control (DMAIC). This roadmap for Six Sigma was used as a stem of the research design. The chosen research approach was discussed, which were quantitative as well as qualitative, giving an overview of the process of the research. Data collection techniques (*historical data and an online survey*) for the two objectives were also discussed. Step by step data treatment procedures were also discussed, for objective one a Chi-Square test and for objective two, a Hypothesis *t* test. The chapter ends by summarizing how work was done in ensuring good quality of the study.

4. CHAPTER 4: DATA ANALYSIS, INTERPRETATION AND DISCUSIONS OF THE RESULTS

4.1 Introduction

To complete the study accordingly, it is necessary to analyze all the data that has been collected in order to test the hypothesis and ensure the research questions are answered. The previous chapter indicates that the data is interpreted in a descriptive fashion. The figure below represents the two main statistics namely: descriptive and inferential statistics. The study followed descriptive statistics in this case.

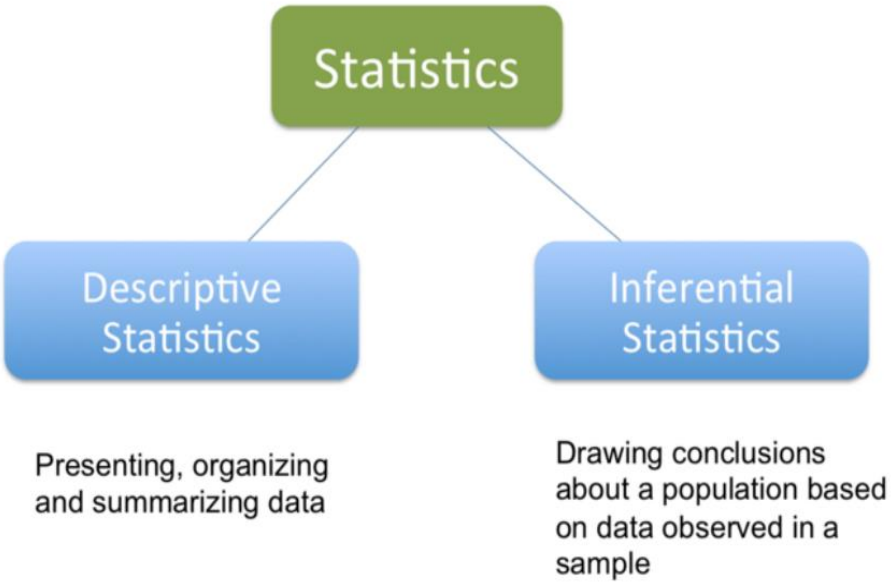


Figure 4-1 Two main areas of statistics (Lane 2019)

This chapter constitutes the analysis, interpretation and discussion of the findings resulting from the study. Since the study must satisfy the two main objectives, the analysis and interpretation of the data collected is also conducted in two categories. The first aspect that addresses objective one, which is based on historical data of outsourced parts and assemblies. The data was obtained from SAP system data base, this deals with a quantitative analysis of data. The second aspect for objective two,

which is based on the results of the survey questionnaire, also is a quantitative analysis.

4.2 Objective 1: Quantitative Interpretation of Results

Analysis of historical data

A total of 42 parts from the Durban manufacturing sector, from a total of 6 business units, was used to compute the results. This was in a form of raw data drawn from a 2-year period. Some of the information included on the raw data include:

Parts and finished goods sold, finished goods received and issued between internal businesses units, parts written off and parts written up, all reversals that took place, outsourced parts received from external suppliers, insourced parts received from internal production into the warehouse, date, quantity, time, unit of measure, material number, material description, cost of parts, finished goods and assemblies.

However not all the mentioned data was used for the results, only the below characteristics were selected and useful for the analysis:

- Material number
- Material Description
- Business Unit
- Entry Date
- Unit of Measure
- Outsource Cost (Rand)
- Price Each
- Insource Cost (Rand)

The table presented below illustrates the sourcing type of each part into a three-cost degree category (low, high and equal). It further shows whether the outsourcing cost is less than, or equal to the insourcing cost, this is presented as a “yes” or a “no” on

the table 4-1. After the classification was completed, the study realized that there were instances where insourcing cost was equal to the outsourcing cost. This occurred on 17 items out of the total sample of 42 items. Although the 17 parts were not further analyzed after this stage, it was essential to show how the study ended up conducting the Chi square analysis on 25 parts as per the contingency table that will follow later in this chapter.

Table 4-1 Sample of outsourced and insourced parts *before* 17 part were eliminated

MAT NO.	MD	UOM	IC(R)	OC(R)	Average (R)	OC<IC (Y/N)	IC	OC
0000001	NUT ROUND;M32,METRIC,2 TPI,STL,HT:43	EA	R 154.51	R 144.76	R 149.64	Yes	High	low
0000002	SUPPORT;MID TRANSOM ,BT-SA BOGIE	EA	R 4,529.64	R 6,000.00	R 5,264.82	No	Low	High
0000003	SUPPORT;PIVOT TRANSOM,BT-SA BOGIE	EA	R 3,239.59	R 6,350.00	R 4,794.80	No	Low	High
0000004	BOLSTER;BOGIE,SARCAST W1/W2 WAGON,CS	EA	R 7,643.16	R 6,051.48	R 6,847.32	Yes	High	low
0000005	CUT, COMP;MK 7 SUBFRAME	EA	R 5,456.34	R 5,585.21	R 5,520.78	No	Low	High
0000006	STRAP RETAINING;BRAKE BEAM,BUNDLE 10	EA	R 86.74	R 96.36	R 91.55	No	Low	High
0000007	ADAPTOR D TYPE BEARING UNIT SG	EA	R 420.29	R 430.36	R 425.33	No	Low	High
0000008	BOLSTER SPOORBABER	EA	R 6,711.82	R 6,400.14	R 6,555.98	Yes	High	low
0000009	SPRING;STABILIZER,STL BLACK	EA	R 432.91	R 432.91	R 432.91	Equal	Equal	Equal
0000010	ADAPTOR;SUBFRAME HS MK7-8,BOGIE	EA	R 25,283.88	R 25,206.02	R 25,244.95	Yes	High	low
0000011	WEDGE RAILWAY BEARING;ADAPTOR,SUBFRAME	EA	R 30.18	R 30.18	R 30.18	Equal	Equal	Equal
0000012	ADAPTOR D TYPE AP BEARING BOGIE MK7	EA	R 686.00	R 773.95	R 729.98	No	Low	High
0000013	BEAM BRAKE 32 LEVER PIN ASSY MK 7	EA	R 6,618.69	R 6,618.69	R 6,618.69	Equal	Equal	Equal
0000014	SPRING;STABILIZER,DIA 14 X OD 78 MM	EA	R 486.96	R 486.96	R 486.96	Equal	Equal	Equal
0000015	SPRING HELICAL COMPR;OD:81 MM,STL BLACK	EA	R 436.32	R 436.33	R 436.33	Equal	Equal	Equal
0000016	SPRING;STABILIZER,SPRING STL OIL TEMPRD	EA	R 508.81	R 508.81	R 508.81	Equal	Equal	Equal
0000017	SPRING HELICAL COMPR;OD:82 MM,STL,INNER	EA	R 398.01	R 398.01	R 398.01	Equal	Equal	Equal
0000018	PLATE METAL;HORNFRAME U PIECE,16 MM,STL	EA	R 853.75	R 1,008.19	R 930.97	No	Low	High
0000019	ASSEMBLY;MOUNT BEAM,JUMBO WAGON	EA	R 4,494.84	R 4,494.84	R 4,494.84	Equal	Equal	Equal
0000020	SUPPORT;BRACKET BOGIE FRAME WELD	EA	R 818.25	R 920.00	R 869.13	No	Low	High
0000021	SUPPORT;YAW DAMPER,BT-SA BOGIE	EA	R 1,733.07	R 1,720.00	R 1,726.54	Yes	High	low
0000022	BOLSTER;BOGIE,SARCAST W1/W2 WAGON,CS	EA	R 5,920.28	R 6,051.48	R 5,985.88	No	Low	High
0000023	SPRING HELICAL COMPR;138 MM,STL,ID:26 MM	EA	R 632.75	R 632.75	R 632.75	Equal	Equal	Equal
0000024	FLANGE GROOVED AIR BRAKES 32mm GROOVE	EA	R 78.98	R 73.18	R 76.08	Yes	High	low
0000025	FLANGE AIR BRAKE PIPE 20mm GROOVE	EA	R 74.91	R 69.11	R 72.01	Yes	High	low
0000026	LINK ACTUATING BRAKE;ADJ	EA	R 293.75	R 426.74	R 360.25	No	Low	High
0000027	HOLDER CARD-LABEL;WAGON,STL,SIL,GALV	EA	R 244.24	R 259.26	R 251.75	No	Low	High
0000028	LEVER;COUPLER RELEASE,STL,WAGON	EA	R 581.16	R 581.16	R 581.16	Equal	Equal	Equal
0000029	HANDLE;COMMODE,LG 570 X THK 25 MM	EA	R 124.37	R 115.83	R 120.10	Yes	High	low
0000030	PLATE WEAR;BOGIE,ROQ-LAST TH400,RECT	EA	R 43.45	R 40.69	R 42.07	Yes	High	low
0000031	BRACKET MOUNT;SUPRT,U/FRAME WAGON	EA	R 225.39	R 225.39	R 225.39	Equal	Equal	Equal
0000032	PLATE MOUNTING;REAR BASE,STL HARDOX 500	EA	R 13,089.80	R 13,089.80	R 13,089.80	Equal	Equal	Equal
0000033	PLATE MOUNTING;FRONT BASE,STL HARDOX 500	EA	R 12,932.20	R 12,932.20	R 12,932.20	Equal	Equal	Equal
0000034	STOP;CONTAINER DOORS LH,STL,SSHR-1 WAG	EA	R 3,363.93	R 4,152.25	R 3,758.09	No	Low	High
0000035	LEVER MANUAL CONTROL;RELEASE ROD,STL	EA	R 276.79	R 276.79	R 276.79	Equal	Equal	Equal
0000036	FLANGE ONLY SWIVEL FLANGE 32	EA	R 99.37	R 99.37	R 99.37	Equal	Equal	Equal
0000037	PAD;PUSHER SUPRT PLATE RH,SS GR 3CR12	EA	R 662.01	R 662.01	R 662.01	Equal	Equal	Equal
0000038	BEND, COMP;PLATES,STL	EA	R 135.44	R 135.44	R 135.44	Equal	Equal	Equal
0000039	CUT, MATERIAL;VARIOUS,LASER	EA	R 330.67	R 355.99	R 343.33	No	Low	High
0000040	STOP MECHANICAL;BACK COMPOSITE BOX,REC	EA	R 2,400.00	R 3,723.26	R 3,061.63	No	Low	High
0000041	CHANNEL STRUCTURAL;U,WD:300 MM,HT:100 M	EA	R 3,837.80	R 4,330.97	R 4,084.39	No	Low	High
0000042	CHANNEL STRUCTURAL;U,WD:300 MM,HT:100 M	EA	R 4,019.55	R 4,330.97	R 4,175.26	No	Low	High

The following table 4-2 shows the 25 parts that were left after eliminating the 17 parts from the 42 total number of the parts. Furthermore, in the chapter, the commencement of commuting the Chi square test took place in a number of steps.

Table 4-2 Sample of outsourced and insourced parts after elimination of 17 items

MAT NO.	MD	UOM	IC(R)	OC(R)	Average (R)	OC<IC (Y/N)	IC	OC
0000001	NUT ROUND;M32,METRIC,2 TPI,STL,HT:43	EA	R 154.51	R 144.76	R 149.64	Yes	High	low
0000002	SUPPORT;MID TRANSOM ,BT-SA BOGIE	EA	R 4,529.64	R 6,000.00	R 5,264.82	No	Low	High
0000003	SUPPORT;PIVOT TRANSOM,BT-SA BOGIE	EA	R 3,239.59	R 6,350.00	R 4,794.80	No	Low	High
0000004	BOLSTER;BOGIE,SARCAST W1/W2 WAGON,CS	EA	R 7,643.16	R 6,051.48	R 6,847.32	Yes	High	low
0000005	CUT, COMP;MK 7 SUBFRAME	EA	R 5,456.34	R 5,585.21	R 5,520.78	No	Low	High
0000006	STRAP RETAINING;BRAKE BEAM,BUNDLE 10	EA	R 86.74	R 96.36	R 91.55	No	Low	High
0000007	ADAPTOR D TYPE BEARING UNIT SG	EA	R 420.29	R 430.36	R 425.33	No	**Low**	High
0000008	BOLSTER SPOORBABER	EA	R 6,711.82	R 6,400.14	R 6,555.98	Yes	High	low
0000010	ADAPTOR;SUBFRAME HS MK7-8,BOGIE	EA	R 25,283.88	R 25,206.02	R 25,244.95	Yes	High	low
0000012	ADAPTOR D TYPE AP BEARING BOGIE MK7	EA	R 686.00	R 773.95	R 729.98	No	Low	High
0000018	PLATE METAL;HORNFRAME U PIECE,16 MM,STL	EA	R 853.75	R 1,008.19	R 930.97	No	Low	High
0000020	SUPPORT;BRACKET BOGIE FRAME WELD	EA	R 818.25	R 920.00	R 869.13	No	Low	High
0000021	SUPPORT;YAW DAMPER,BT-SA BOGIE	EA	R 1,733.07	R 1,720.00	R 1,726.54	Yes	High	low
0000022	BOLSTER;BOGIE,SARCAST W1/W2 WAGON,CS	EA	R 5,920.28	R 6,051.48	R 5,985.88	No	Low	High
0000024	FLANGE GROOVED AIR BRAKES 32mm GROOVE	EA	R 78.98	R 73.18	R 76.08	Yes	High	low
0000025	FLANGE AIR BRAKE PIPE 20mm GROOVE	EA	R 74.91	R 69.11	R 72.01	Yes	High	low
0000026	LINK ACTUATING BRAKE;ADJ	EA	R 293.75	R 426.74	R 360.25	No	Low	High
0000027	HOLDER CARD-LABEL;WAGON,STL,SIL,GALV	EA	R 244.24	R 259.26	R 251.75	No	Low	High
0000029	HANDLE;COMMODE,LG 570 X THK 25 MM	EA	R 124.37	R 115.83	R 120.10	Yes	High	low
0000030	PLATE WEAR;BOGIE,ROQ-LAST TH400,RECT	EA	R 43.45	R 40.69	R 42.07	Yes	High	low
0000034	STOP;CONTAINER DOORS LH,STL,SSHR-1 WAG	EA	R 3,363.93	R 4,152.25	R 3,758.09	No	Low	High
0000039	CUT, MATERIAL;VARIOUS,LASER	EA	R 330.67	R 355.99	R 343.33	No	Low	High
0000040	STOP MECHANICAL;BACK COMPOSITE BOX,REC	EA	R 2,400.00	R 3,723.26	R 3,061.63	No	Low	High
0000041	CHANNEL STRUCTURAL;U,WD:300 MM,HT:100 M	EA	R 3,837.80	R 4,330.97	R 4,084.39	No	Low	High
0000042	CHANNEL STRUCTURAL;U,WD:300 MM,HT:100 M	EA	R 4,019.55	R 4,330.97	R 4,175.26	No	Low	High

4.2.1 Chi Square Data Analysis

4.2.1.1 Null and alternative hypothesis

As stated in the previous chapter, the study's null and alternative hypothesis are as follows:

H_0 : The cost rate of insourced parts is not different to that of outsourced parts.

H_1 : The cost rate of insourced parts differs to that of outsourced parts.

4.2.1.2 Six Steps of hypothesis testing

Step 1

Numbers across columns and rows were added, then the total number in chat was calculated.

Cost degree	Sourcing Type: Insource	Outsource	
High	9	16	**25**
Low	16	9	**25**
	25	**25**	**50**

Step 2

Expected numbers for each individual cell were calculated, (i.e. the frequencies one expected to obtain, since there was no association between the two variables. This was achieved by multiplying row sum by column sum and dividing by the total number.

Expected Frequency = (Row Total x Column Total) / Grand Total

Using the first cell in table (Insource/High);

Insource Cost

=12.5

Using the second cell in table (Insource/Low);

(25x25)/50

Insource Cost

=12.5

Using the third cell in table (Outsource/High);

Insource Cost

=12.5

Using the fourth cell in table (Outsource/Low);

(25x25)/50

Insource Cost

=12.5

After the calculations were completed in this step, the below chart was done to indicate the consolidated figure.

Sourcing Type

Cost degree	Insource	Outsource	
High	12.5	12.5	**25**
Low	12.5	12.5	**25**
	25	**25**	**50**

Step 3

Now the observed number and expected number was available. The observed number is the number in the first chart. The expected number is the number in the last step (step 2). Contingency table was then redone, this time, by adding in the expected frequencies in brackets below the obtained frequencies:

Sourcing Type

Cost degree	Insource Cost	Outsource Cost	
High	9 *(12.5)*	16 *(12.5)*	**25**
Low	16 *(12.5)*	9 *(12.5)*	**25**
	25	**25**	**50**

Step 4

Now the Chi Square was calculated using the formula below:

X^2 - Chi-square value

O - Observed

E- Expected

$$\chi^2 = \sum \frac{(O-E)^2}{E} \quad \text{...or...} \quad \chi^2 = \text{Sum of } \frac{(\text{Observed - Expected})^2}{\text{Expected}}$$

Using the first cell in table (Insource/High);

= (9-12.5)²/12.5

= 0.98

Using the second cell in table (Insource/Low);

= (16-12.5)²/12.5

= 0.98

Using the third cell in table (Outsource/High);

= (16-12.5)²/12.5

= 0.98

Using the fourth cell in table (Outsource/Low);

$$= (9-12.5)^2/12.5$$

$$= 0.98$$

Step 5

Adding together all the final numbers for each cell obtained in Step 4. Basically, there are 4 total cells, this means that at the end, four numbers were added together for the final Chi Square number as follows:

$$=0.98+0.98+0.98+0.98$$

$$=\mathbf{3.920}$$

This means that **3.920** obtained value was the Chi Square. This is a single-number summary of the discrepancy between the obtained frequencies, and the frequencies which the study would expect if there was no association between the two variables. The bigger this number, the greater the difference between the observed and expected frequencies.

Step 6:

(a) Calculating degrees of freedom was the next step:

= (Number of rows-1) x (number of columns-1)

= (R-1) x (C-1)

= (2-1) x (2-1)

= 1x1

= **1** ***df (degree of freedom)***

(b) Establishing the probability level was the next sub step, **p < 0.05** was used as standard, this was represented by the 5% column.

(c) This is the step where the table of "critical values of Chi Square" was consulted.

Chi-Square (χ^2) Distribution

Degrees of Freedom	Area to the Right of Critical Value									
	0.995	0.99	0.975	0.95	0.90	0.10	0.05	0.025	0.01	0.005
1	—	—	0.001	0.004	0.016	2.706	3.841	5.024	6.635	7.879
2	0.010	0.020	0.051	0.103	0.211	4.605	5.991	7.378	9.210	10.597
3	0.072	0.115	0.216	0.352	0.584	6.251	7.815	9.348	11.345	12.838
4	0.207	0.297	0.484	0.711	1.064	7.779	9.488	11.143	13.277	14.860
5	0.412	0.554	0.831	1.145	1.610	9.236	11.071	12.833	15.086	16.750
6	0.676	0.872	1.237	1.635	2.204	10.645	12.592	14.449	16.812	18.548
7	0.989	1.239	1.690	2.167	2.833	12.017	14.067	16.013	18.475	20.278
8	1.344	1.646	2.180	2.733	3.490	13.362	15.507	17.535	20.090	21.955
9	1.735	2.088	2.700	3.325	4.168	14.684	16.919	19.023	21.666	23.589
10	2.156	2.558	3.247	3.940	4.865	15.987	18.307	20.483	23.209	25.188
11	2.603	3.053	3.816	4.575	5.578	17.275	19.675	21.920	24.725	26.757
12	3.074	3.571	4.404	5.226	6.304	18.549	21.026	23.337	26.217	28.299
13	3.565	4.107	5.009	5.892	7.042	19.812	22.362	24.736	27.688	29.819
14	4.075	4.660	5.629	6.571	7.790	21.064	23.685	26.119	29.141	31.319
15	4.601	5.229	6.262	7.261	8.547	22.307	24.996	27.488	30.578	32.801

Figure 4-2 Critical value of X^2 *table (Aslam 2021)*

(d) The values in each column are "critical" values of Chi Square. These values would be expected to take place by chance with the probability displayed at the top of the column on the table in figure 4-3 above, appendix 4 also shows a full table. The relevant value for this test is found at the intersection of the

applicable *df* row and probability column. Since the study's Chi Square has a *df* 1, the interest is on the 1 *df* row. As the probability level is **p = 0.05,** the study then looked in the 5% column to find the critical value for this statistical test. The critical value in this case was **3.841**.

Ultimately, the study managed to compare obtained Chi Square to the critical value. If the acquired Chi Square is greater than a value in the table, this implies that it is doubtful to have occurred by chance. The study's acquired value of **3.920** greater than the critical value of **3.841.**

4.2.2 Results Discussion

4.2.2.1 Chi-Square Overview

For the first aspect of the study, the primary use of the Chi- Square was to examine whether two variables are independent or not. So, what does it mean to be independent in this particular sense? The meaning stipulates those two factors are not related. Usually in social sciences research, the interest is in finding factors that depend on each other, for example, occupation and prestige, voting behavior and age, education and income. Chi-Square can be used to assess whether two variables are, in fact dependent or not dependent, by ruling out independence of the two variables. (Paul, Thakar and Patel 2021).

Furthermore, it generally said that one variable is not correlated with or independent of the other. This apply if an increase in one variable is not associated with an increase on the other one (Shen, Panda and Vogelstein 2021). When two variables correlated, their values usually move together. The values can either move together either in the same direction or the opposite direction.

4.2.2.2 Chi-Square Distribution

The Chi- Square distribution is similar to *t* distribution. It is basically a series of distributions and the shape is determined by the degrees of freedom. However, unlike

the *t* distribution, the Chi-Square distribution is non-uniform, never approaches normality and positively skewed. How the shape of the Chi-Square distribution changes as the degree of freedom(k) increase is illustrated on the graph below:

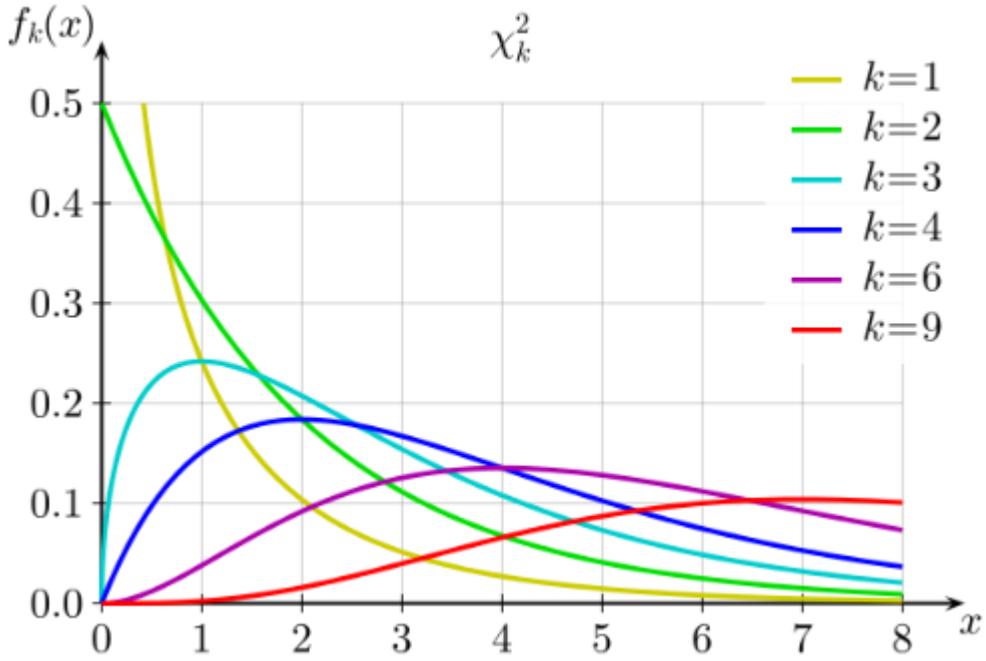


Figure 4-3 Chi-Square distribution and degree of freedom graph (Paul, Thakar and Patel 2021)

4.2.2.3 Interpretation

Regarding the hypothesis that was tested, all Chi-Square tests generally have the same null and research hypothesis. As mentioned earlier in study, null hypothesis states that there is no relationship between the two variables. On the other hand, the research hypothesis states that there is a relationship amongst the two variables. The test statistics followed a Chi- Square distribution. The study used this type of distribution in order to determine whether there is a relationship between sourcing type and cost degree at TE (both nominal variables). As mentioned earlier raw scores were presented as below:

		Sourcing Type		
		Insource	**Outsource**	
Cost degree	**High**	9	16	**25**
	Low	16	9	**25**
		25	**25**	**50**

To examine statistically whether the outsource cost in TE Durban was more often high, the hypothesis needed to frame the question in terms of hypotheses. In Chapter 3 (Methodology), the study mentioned that if the Chi Square calculated value is greater than the Chi- Square critical value, then the null hypothesis is rejected (Onesime, Yang and Dai 2021). In this case the Chi-Square calculated value was 3.902 and the Chi-Square critical value obtained was 3.841. The study concluded with confidence that observed frequencies are significantly different from the frequencies that the study would expect to acquire if all categories were equally distributed. This means that, there is enough evidence that outsourcing cost is generally high than insourcing cost at TE Durban, hence the rejection of the null hypothesis.

Table 4-3 Chi Square Test Summary Results: Objective 1

Hypothesis	Null	Alternative
	The cost rate of insourced parts is not different to that of outsourced parts	*The cost rate of insourced parts differs to that of outsourced parts.*
Reject/Fail to reject	Reject √	Fail to reject
Question	*Does outsourcing cost differ from insourcing ?*	
Degree of freedom(*df*)	1	
Probability Level (p)	0,05	
Chi Square Calculated Value	3,920	
Chi Square Critical Value	3,841	
Chi Square Calculated vs Critical Value	Critical Value < **Calculated Value**	

4.2.3 Limitations of the Chi- Square Test

- Sensitive to sample size- If the study only required 5 employees to participate on the study, this would be insensitivity to the sample size. However, assessing the views of 40 employees yielded a much more realistic sampling and was more representative of the population. With a big enough sample, even trivial relationship can appear to be statistically significant.
- One should keep in mind that “statistically significant” does not mean “meaningful” when using the Chi-Square test. Be mindful that the chi-square can only be used to determine which one is more expensive between producing in house and outsourcing. It does not necessarily follow that one variable has a causal relationship with the other.

4.3 Objective 2: Quantitative Interpretation of Results

Analysis of survey questionnaire in statement form

There were a total 440 questionnaires distributed and completed, however the base for computing the results was from 321 completed questionnaires. This means that 119 out of 440 questionnaires distributed, were deserted from the analysis. The balance of 321 questionnaires was then used to interpret the results.

4.3.1 Bar Chart Data Interpretation

The responses were displayed in a bar chart figure 4-4 to 4-14 format downloaded from google forms computer application that was utilized to conduct the survey, where the x-axis reflects the level of agreement and y-axis shows the number and percentage of employees who responded.

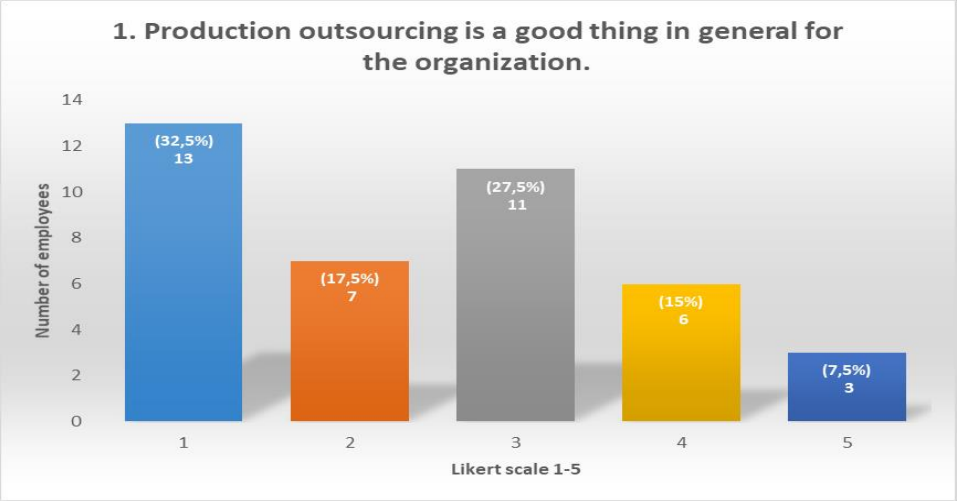


Figure 4-4 Outsourcing a good practice

This bar chart figure 4-4 shows that 13 (32.5%) of the subjects stronlgy disagree that production outsourcing is a good thing in general for TE Duabn. On the othe hand, 7(17.5%) also disagrees, followed by 11 (27.5%) who are neautral and did not indicate where they are agree or not. Another 6 (15%) subjects agree, furthermore, only 3 (7.5%) stronlgy agree that outsourcing of production is generally a good practise for the organissation.

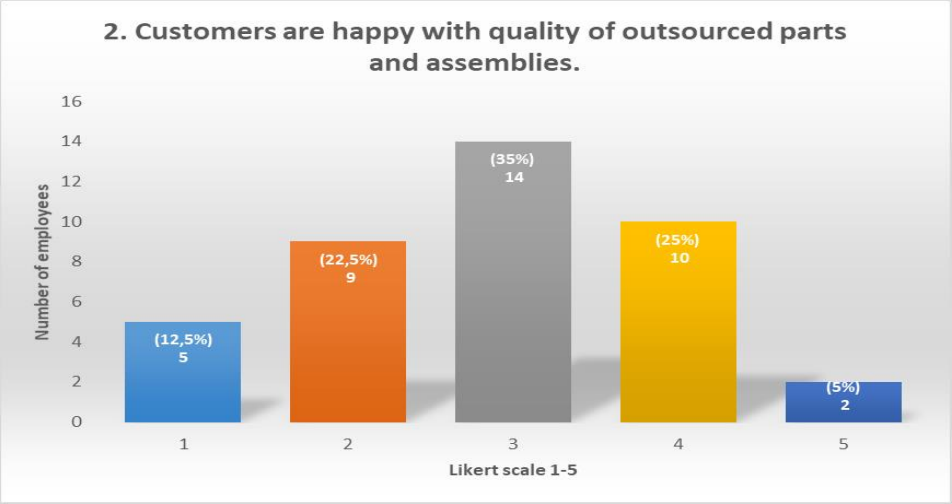


Figure 4-5 Customer happiness

While, this bar figure 4-5 chart shows that only 5 (12.5%) of the employees stronlgy disagree that TE Durban customers are happy with quality of outsourced parts after delivery. The study then had 9 (22.5%) that also disagree, followed by a couple of 14 (35%) who are neutral, this group did not indicate whether they agree or not hence an opportunity was given to them to indicate why they do not agree nor agree. Another 10 (25%) subjects agree, furthermore, only 2 (5%) stronlgy agree the clients are happy about the quality of the parts supplied.

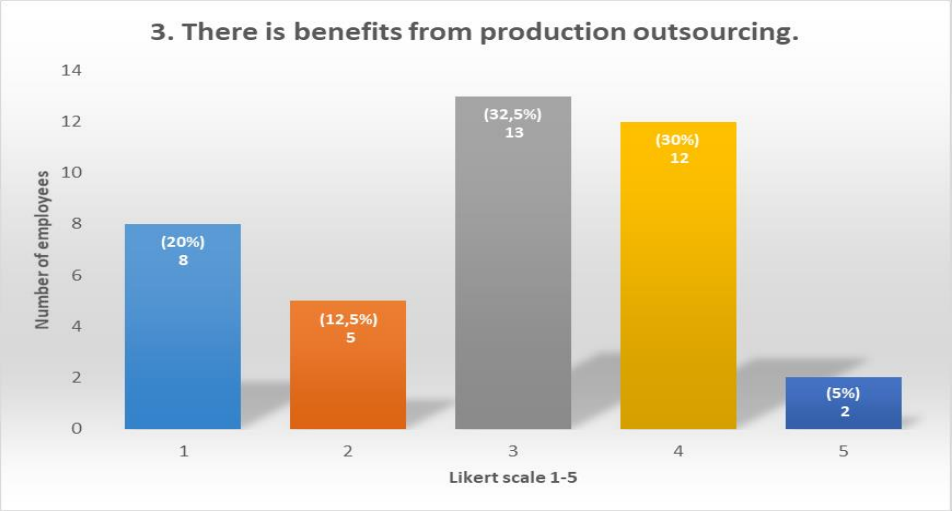


Figure 4-6 Benefits in outsourcing

However, figure 4-6 show that most employees agree 2 (5%) and strongly agree 12 (30%) that benefits in outsourcing production do exist. For this statement, overall, the employees show positive response regarding the benefits of this practice. Only 5 (12.5%) disagree, 13 (32.5%) neutral and 8 (20%) strongly disagree and do not believe there are benefits from this practice.

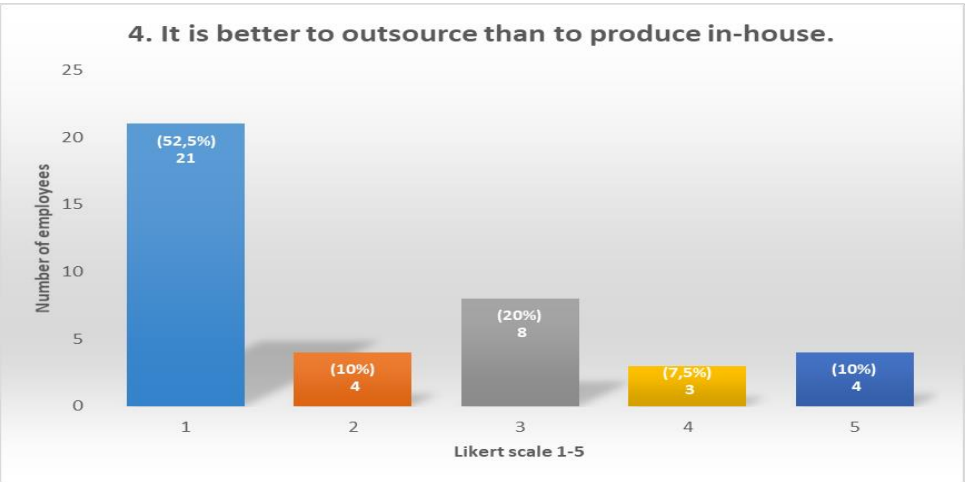


Figure 4-7 Outsource over insource

This bar chart on figure 4-7 clearly display that the subjects do not believe that in-house is less superior than outsourcing. This can be seen by a huge number of 21 (52.5%) that strongly disagree and 4 (10%) that disagree, with 8 (20%) that is neutral as well as only 3 (7.5%) that agree.

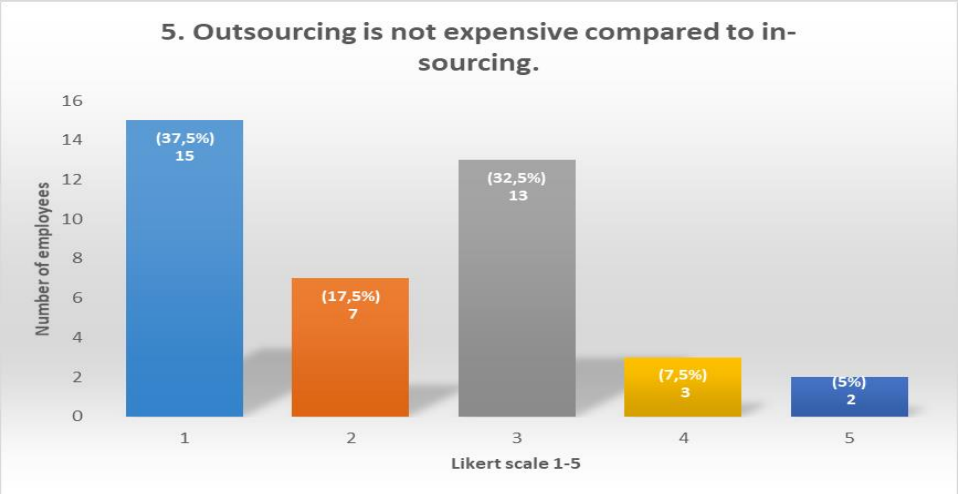


Figure 4-8 Outsource vs insource cost

Again, like the previous statement, figure 4-8 shows a huge number of employees do not agree that outsourcing is not expensive. This was shown by 15 (37.5%) that strongly disagree, 7 (17.5%) that disagree, 13 (32.5%) neutral, 3 (7.5%) that agrees as well as 2 (5%) that strongly agrees that outsourcing is not expensive.

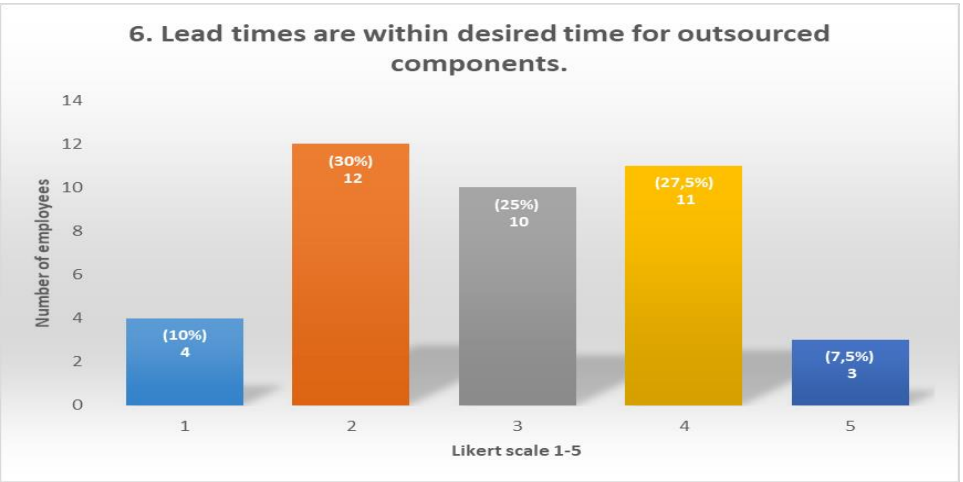


Figure 4-9 Outsource lead-times

One of the most important key performance indicators for outsourcing is lead time. The subjects' responses were also showing almost equal distribution for a group of employees that disagree 12 (30%), 10 (25%) neutral and 11 (27.5%) that agree. Figure 4-9 shows that there was a 4 (10%) that strongly did not agree at all that lead times are within the desired time frame specifically for outsourced parts. Lastly, on 3 (7.5%) strongly agree regarding the lead-times.

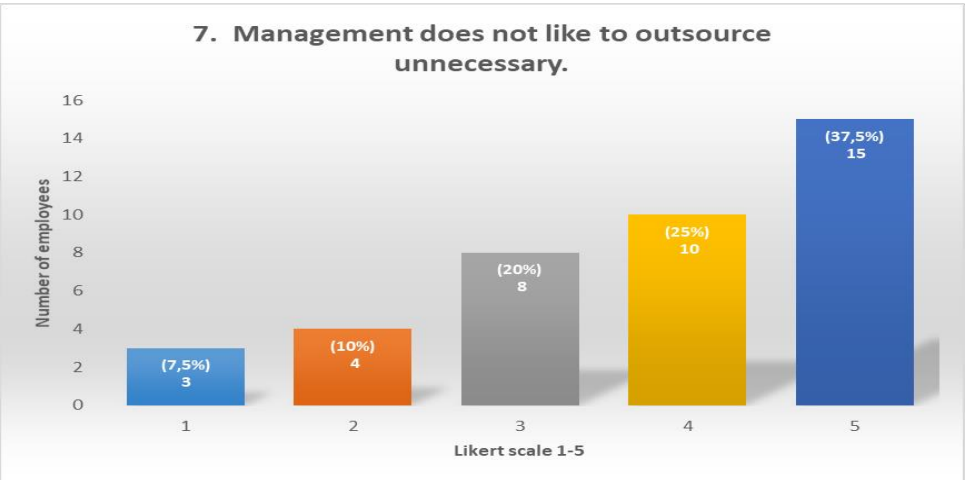


Figure 4-10 Management and outsourcing decision

It is usually a management decision to make in organizations when there is a need to outsource some portion of production activities. Figure 4-10 shows that about 15 (37.5%) employees strongly agree that management does not outsource when there is no particular need to do so. They only outsource when it is rather necessary. Around10 (25%) also agree, while 8 (20%) is neutral, then 4 (10%) do not agree, where else only 3 (7.5%) strongly disagree that management practices this norm unnecessarily. The study also notes that in some cases, a big portion of employees usually does not agree nor disagree with the statements which made the researcher to encounter minor challenges in drawing a conclusion.

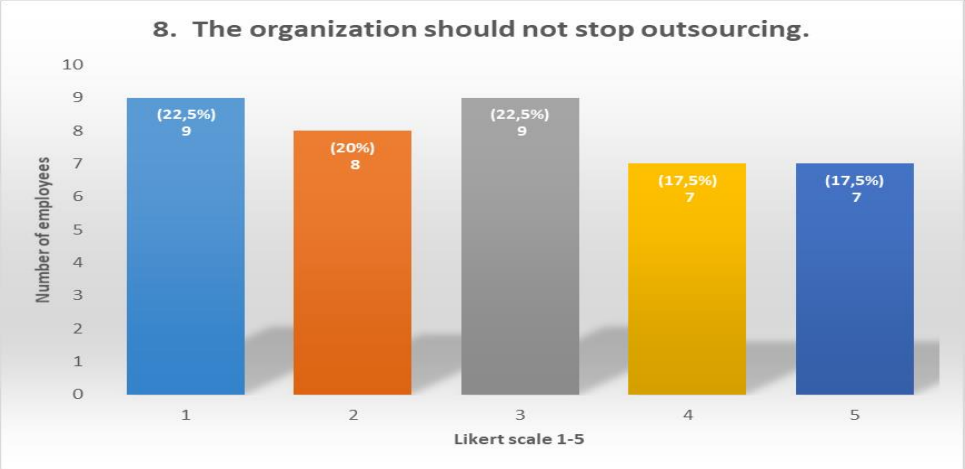


Figure 4-11 Outsource practice

The bar chart figure 4-11 shows results that are almost equal, even by looking at the five bars, it clearly shows that for this statement, almost an equal number of employees per Likert scaling exits. There is about 9 (22.5%) of employees that strongly disagree that the organization should not stop with this practice. While 8 (20%) disagrees, another 9 (22.5%) is neutral, furthermore 7 (17.5%) agrees, and then another 7 (17.5%) strongly agree.

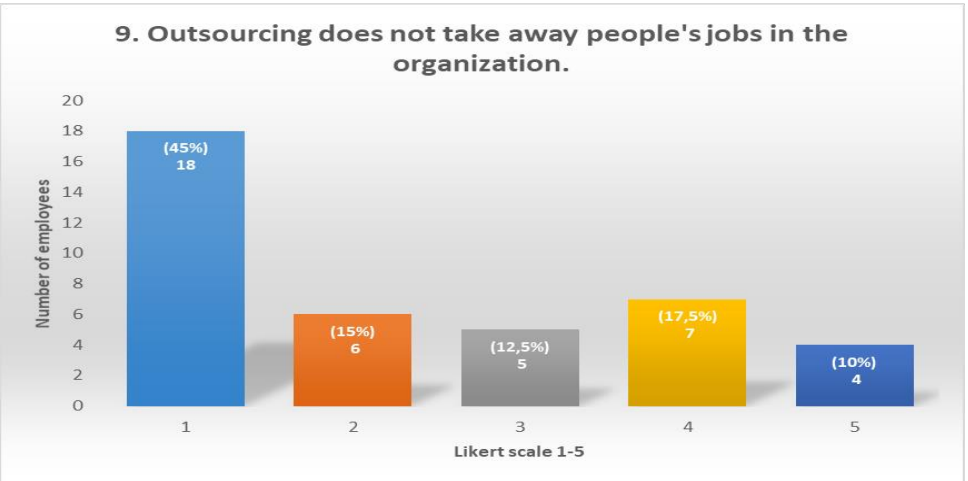


Figure 4-12 Outsource effect on employee jobs

This was one of the most sensitive statement the employees had to respond to due to that it is speaking about the jobs of employees. The study sensed some panic based on results shown in figure 4-12, 18 (45%) strongly disagreed, followed by 6 (15%) that disagree. One could tell already that outsourcing is not always a topic employee would like to hear. Furthermore, 5 (12.5%) is neutral, 7 (17.5%) agrees and lastly only 4 (10%) strongly agrees that outsourcing does not reduce work availability for employees and lead to retrenchments.

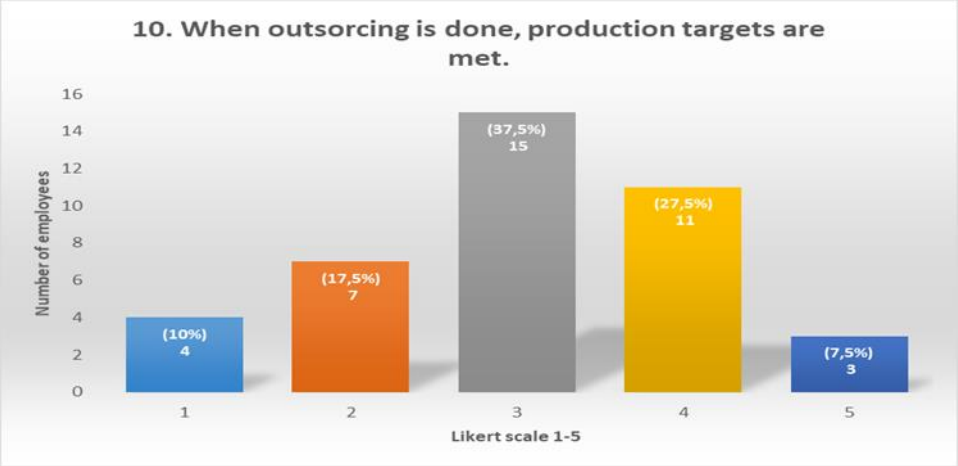


Figure 4-13 Outsource and production targets

Figure 4-13 shows that when outsourcing is practiced, only 4 (10%) employees strongly disagree that production targets are met. Followed by 7 (17.5%) who also disagree, 15 (37.5%) do not agree nor agree to this statement. There are also 11 (27.5%) employees who agree, and lastly only 3 (7.5%) also strongly agree that targets are met. A huge number of employees from the sample is really not sure whether production targets are met or not.

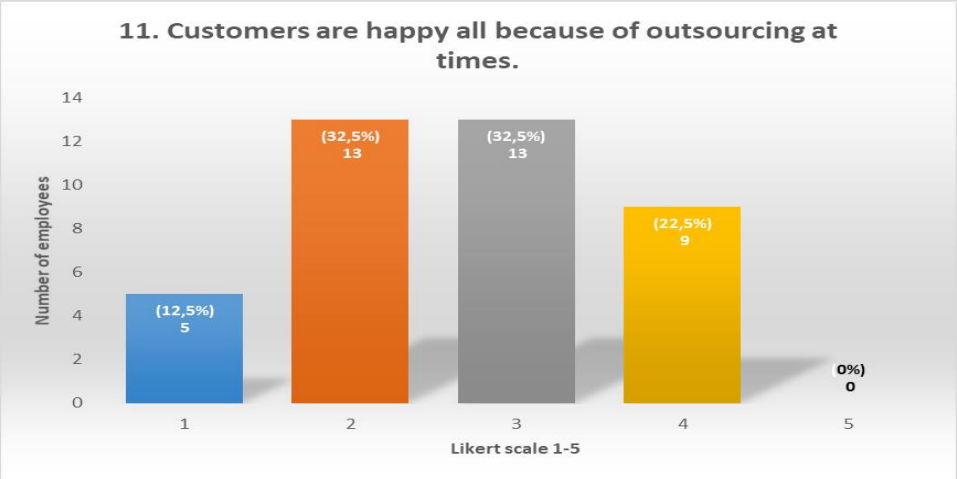


Figure 4-14 Customer satisfaction

On figure 4-14, not even one employee strongly agrees that customers are happy because of outsourcing at times. Only 5 (12.5%) strongly disagree, with 13 (32.5%) who agree, an equal percentage of 13 (32.5%) also for neutral employees, then 9 (22.5%) agree that customers are happy due to outsourcing in the organization. There is 0 (0%) employees who strongly agree that TE customers are happy due to outsourcing.

The responses were displayed in a bar chart format downloaded from google forms computer application that was utilized to conduct the survey, where the x-axis reflects the level of agreement and y-axis shows the number and percentage of employees who responded.

4.3.2 Hypothesis *t* Test Data Analysis

For this objective, which is the second, a hypothesis t-test was used to analyze the set of data collected. One would ask why a hypothesis test was adapted because the

results are already displayed on the bar charts. One of the reasons is that the t-test is best to compare two means of groups (*agree and disagree*) in this case, as mentioned in the previous chapter. This helped the researcher to achieve more accurate results as possible before drawing a conclusion. The following steps were followed in analyzing data for objective two:

Step 1 - State the null alternative hypotheses.

The null hypothesis and alternative hypothesis were as follows:

H_0 : There is no difference between number of employees who agree versus who disagree regarding production outsourcing influence.

H_1 : There is a difference between number of employees who agree versus who disagree regarding production outsourcing influence.

$$H_0 : \mu_1 = \mu_2$$
$$H_a : \mu_1 \neq \mu_2$$

The table below shows the two response types for employees.

Table 4-4 Employee response data categorized by response type

Category	Agree	Disagree
Employee Responses	9	20
	12	14
	14	13
	7	25
	5	22
	14	16
	25	7
	14	17
	11	24
	14	11
	9	18

The following table displays response types with average, standard deviation as well as sample size.

Table 4-5 Average, standard deviation and sample size statistics categorized by response type

Category	Agree	Disagree
Sample Size	11	11
Average (X-bar)	12.18	17
Standard deviation (s)	5.269	5.568

Step 2 - Choose significant level – α.

The degree of freedom was then calculated, with a 0.05 significance level.

$$df = n1 + n2 - 2$$

= 11 + 11 – 2

= 20

Since this is a two tailed t- test, significance level = **0.025 (0.05/2)** for right and left. tail.

Step 3 - Set the criteria (critical values) for rejecting the null hypothesis.

The critical value was then established by first establishing an alpha level establishing an alpha level using the *t* distribution table, a full table available on appendix 5.

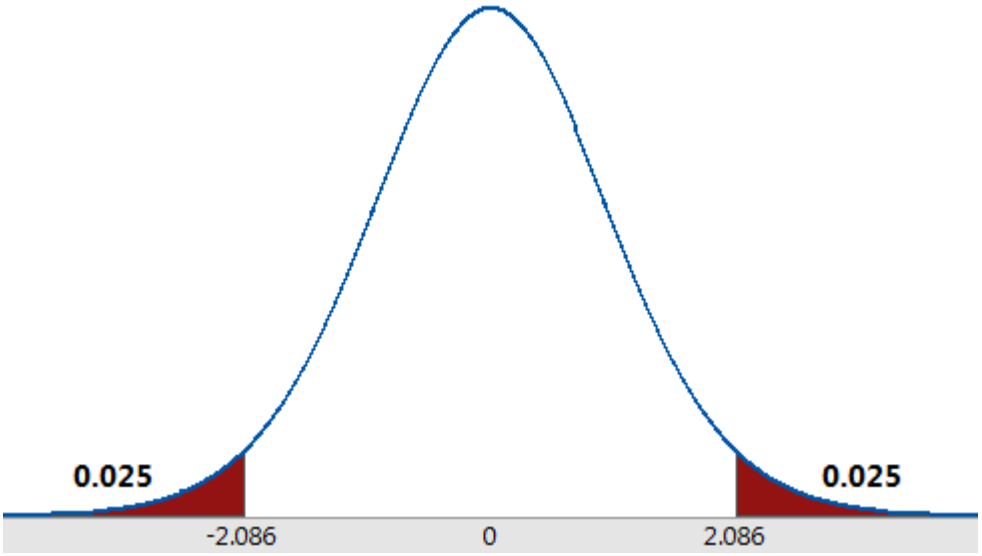


Figure 4-15 T- distribution plot two-tails

alpha = 0.05

degree of freedom = 20

Critical value

= **2.086**

In these two tailed tests, it will be tested whether the sample is greater or less than the range of values. Null hypothesis testing and statistical testing significance will be tested. If the sample being tested falls into either of the critical areas, the alternative hypothesis is accepted instead of null hypothesis. For this objective, by convention, a two-tailed test was used to determine significance at the 5% level, this means that each side of the distribution is cut at 2.5% as show on figure above.

Step 4 – Compute the test.

Additional to the above tables, the below table with values was computed using Microsoft Excel. More calculations were completed by utilizing the table below:

Table 4-6 Sample 1 and 2 table

n1	x1	x1-x̄1	(x1-x̄1)²	n2	x2	x2-x̄2	(x2-x̄2)²
S1	9	-3,18	10,11	S1	20	3	9
S2	12	-0,18	0,03	S2	14	-3	9
S3	14	1,82	3,31	S3	13	-4	16
S4	7	-5,18	26,83	S4	25	8	64
S5	5	-7,18	51,55	S5	22	5	25
S6	14	1,82	3,31	S6	16	-1	1
S7	25	12,82	164,35	S7	7	-10	100
S8	14	1,82	3,31	S8	17	0	0
S9	11	-1,18	1,39	S9	24	7	49
S10	14	1,82	3,31	S10	11	-6	36
S11	9	-3,18	10,11	S11	18	1	1
	134		**277,64**		**187,00**		**310**

The test statistics was calculated, but before it was calculated, a pooled estimate variance from the sample had to be found. When testing a hypothesis for two independent samples, there is a need to calculate the estimated standard error of the difference between the sample means first.

$$s_{\bar{x}_1 - \bar{x}_2} = \sqrt{s^2 \left(\frac{1}{n_1} + \frac{1}{n_2} \right)}.$$

= √29.382 (√1/11+√1/11)

= 5.42 √ (0.09 +0.09)

=5.42 (√0.18)

= 5.42 (0.42)

= **2.276**

Where:

Sizes of the two samples are represented as below:

$$n_1 \text{ and } n_2$$

n1 = **11** and n2 = **11**

Pooled sample variance is represented below:

$$s^2$$

Calculated as follows:

$$s^2 = \frac{\sum (x_1 - \bar{x}_1)^2 + \sum (x_2 - \bar{x}_2)^2}{n_1 + n_2 - 2}$$

But the formula often expressed as below, simplified by substituting *SS* for the sum of squared deviations:

$$s^2 = \frac{SS_1 + SS_2}{n_1 + n_2 - 2}$$

= (277.64 + 310)/20

= **29.382**

At this step, data from the two groups is presented. Calculating the test statistic for independent samples is a bit different since the study deals with two sets of data. The below formula is used to calculate the test statistics:

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{s.e.(\bar{x}_1 - \bar{x}_2)}$$

In this instance, the hypothesized difference is zero, so the T-Statistic formula reduces to:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{SE}$$

= (17 – 12.18)/2.29

= 4.82/2.29

= **2.104**

Where:

$\bar{x}_1 - \bar{x}_2$ is the difference between the sample means

$\mu_1 - \mu_2$ is the difference between the hypothesized population means

$s.e.(\bar{x}_1 - \bar{x}_2)$ is the standard error of the difference between sample means

4.3.3 Results Discussions

Step 5 - Make a decision, reject or fail to reject the null hypothesis.

Just a reminder from the literature in previous chapter, when the *t* value is more than critical level, the study rejects the null hypothesis. This means that the data favors the alternative hypothesis, the results would then be statistically significant. However, if the *t* value is less than the significance level, the study fails to reject the null hypothesis and the results will not be significant (Walker 1995).

For this study, *t* value is **2.104**, and significant level is **2.086**. This means that the study rejects the null hypothesis, therefore the results are significant. To evaluate the difference between the means in order to decide about the employee responses, the study compared the test statistic to the theoretical value from the *t* distribution.

Step 6 - Interpret the decision within the context of the problem.

The decision will depend on the *t* value obtained in step 5 which was already obtained. Therefore it would be concluded that employees do not think production outsourcing is effective if the *t* value was equal or less than the signifcant level. However the *t* value if greater than the significance level, then this means that, employees do think that production outsourcing is effcetive through yelding positve reults by managing and supporting increased demand. This is simpy because the null hypotheses that states that sample means are equal was not rejcted.

4.3.4 Limitations of The Hypothesis *t* Test

- This type of test can only used to compare two groups. If used to compare more than two groups, type-I error may occure. For this study, agree and disagree groups were compared. The t test is also known to be highly sensitive to sample sizes (n>30), for this this study sample 1 is 11 as well as sample 2, if the sample was more than 30, a z test would be more suiable for the study.
- The data for this study is normally distributed, this means that it is symmetrically distributed with no skew. When plotted on a graph, the data follows a bell shape, with most values clustering around a central region and tapering off as they go further away from the center.
- An assumption that there is equality of variances between the groups was also made for this test.

4.3.5 Two sample t Test Assumptions

- The data are continuous (not descrete).
- The data variences of the two populations are equal.
- The data follows the nromal probabilty distribution.
- Both sampels are simple random samples from their respctive population.
- The two samples are independent.

4.4 Conclusion

AB Ltd problem of not meeting monthly targets as well as producing products at high cost will be managed better, with the evidence from the results drawn from the study. For aspect one, the study shows that outsourcing cost in not necessarily lower than insourcing cost, and the costs are also not equal. This data will be useful to AB Ltd management making outsourcing decision. Additionally, management will pay attention to other challenges related to production efficiency in the organization as we well as to manage outsourcing practice better than before. For aspect two, the results are related to the confidence the employees have when it comes to production

outsourcing. This has direct impact to overall efficiency due to that if employees do not have pride and confidence about any practice in the company, the overall efficiency is limited and compromised. A buy in from the employees is necessary when management is dealing outsourcing decisions. As mentioned in the chapter, the study has two objectives and with two data analysis techniques, that made this possible.

5. CHAPTER 5: CONCLUSIONS AND FUTURE RECOMMENDATIONS

5.1 Introduction

This chapter gives the conclusions concerning the research problem and the hypotheses. It also provides the research findings, recommendations where shortfalls are identified, limitations, and conclusion. The chapter also provides directions for additional research that will further assist the rail-manufacturing sector and any other relevant sector in making the best outsourcing decisions for organizations.

5.2 Statement of The Research Problem

The aim of this research is to evaluate the cost to outsource some production activities versus in-house. Furthermore, assess production outsourcing influence in the changing demand patterns and its influence on AB Ltd customer satisfaction. The research compromised of two objectives namely:

- To investigate how production outsourcing could reduce production costs.
- To investigate how production outsourcing has influence to manage and support increased customer demands.

5.3 Research Hypotheses Statements

The research hypotheses based on the two objectives are:

Hypothesis statement 1: Production outsourcing cost is same as in-house production cost.

Hypothesis statement 2: Production outsourcing has influence in managing and supporting increased customer demands.

5.4 Summary of The Findings and Conclusions

5.4.1 Objective 1

For the first aspect, the findings are splits into two categories:

- Firstly, it is established that the cost to insource is less than the cost to outsource. As per below table, the average unit cost is R2 866.44 in-house, and the average unit cost is R3 015.66 during outsourcing. The total cost is also provided by the table as R78 348.97 for insource, and R84 616.20 for outsource. This summary of results addresses the first objective.

Table 5-1 Summary results of cost prices

Source Type	Avearge Unit Cost	Total Unit Cost	Number of Parts
Production Insourcing	R 2 866,44	R 78 348,97	25
Production Outsourcing	R 3 015,66	R 84 616,20	25

- Secondly, in reference to the above table 5-1, summary results provide a comparison of the two set of costs based on data collected from SAP over the two years at AB Ltd. This was completed in order to address objective one as stated in previous chapter. However, the study had to further conduct a Chi-square test through hypothesis in order to see the significance of the results. The Chi- square test was then used to reject the null hypothesis, below is table 5-2 that indicates the test summary of the results:

Table 5-2 Chi square test results through hypothesis

Hypothesis		Results
H:0 (null)	*The cost rate of insourced parts is not different to that of outsourced parts.*	**Reject**
H:1 (alternative)	*The cost rate of insourced parts differs to that of outsourced parts.*	Fail to reject
Chi Square	**Value**	
Calculated Value	**3,920**	**Greater**
Critical Value	**3,841**	Less

The conclusion is that the cost rate of insourced parts differs to that of outsourced part. This therefore means that production outsourcing does not necessarily reduce production costs for AB Ltd. The same parts were studied during outsourcing and when manufactured internally.

5.4.2 Objective 2

The questionnaire in statement form distribution and completion by AB Ltd employees was a total of 440. Results were computed from 321 responses because 119 of the response were neutral and eliminated for further analysis. This means that the employees did not agree nor disagree to the statement posed on the 119 responses hence the study decided not further analyses and consider this data.

Table 5-3 Summary results from survey

	Statement	Responses				
No.		Agree no.	Agree Percentage	Disagree no.	Disagree Percentage	Total Responses
1	*Production outsourcing is a good practice in general for the organization.*	9	3%	20	6%	29
2	*Customers are happy with quality of outsourced parts and assemblies.*	12	4%	14	4%	26
3	*There is benefits from production outsourcing.*	14	4%	13	4%	27
4	*It is better to outsource than to produce in-house.*	7	2%	25	8%	32
5	*Outsourcing is not expensive compared to in-sourcing.*	5	2%	22	7%	27
6	*Lead times are within desired time for outsourced components.*	14	4%	16	5%	30
7	*Management does not like to outsource unnecessary.*	25	8%	7	2%	32
8	*The organization should not stop outsourcing.*	14	4%	17	5%	31
9	*Outsourcing does not take away people's jobs in the organization.*	11	3%	24	7%	35
10	*When outsourcing is done, production targets are met.*	14	4%	11	3%	25
11	*Customers are happy all because of outsourcing at times.*	9	3%	18	6%	27
	Totals	**134**	**42%**	**187**	**58%**	**321**

Based on the summary results on table 5-3, conclusion shows that 58% of employees disagree that production outsourcing has influence in managing and supporting increased customer demands. Moreover, 42% of the employees agree that production outsourcing has influence in managing and supporting increased customer demands. Even though the results were of this nature, the study additionally tested their significance by using a t test.

Below table 5-4 illustrates the summary results of the t test. The t test illustrate that the t value is 2.104, and the critical value is 2.086. This means that the study rejects the null hypothesis because the t value is greater than the critical value. The alternative hypothesis is then supported based on these results.

Table 5-4 Hypothesis t-test results

Hypothesis		Results
H:0 (null)	*There is no difference between number of employees who agree versus who disagree regarding production outsourcing influence.*	**Reject**
H:1 (alternative)	*There is a difference between number of employees who agree versus who disagree regarding production outsourcing influence.*	Fail to reject
Values		
T-test	**2.104**	**Greater**
Critical	**2.086**	Less

The study concluded that production outsourcing does not have positive influence in managing and supporting increased customer demands. This was based on the null hypothesis that was rejected; hence the study supported the alternative hypothesis.

5.5 Recommendations

Based on the study findings, the recommendations were made for AB Ltd.

- It is recommended that AB Ltd outsources the right components. Outsourcing is a huge step, the question of which components to outsource is one of the most important. It is important not give up AB Ltd's competitive advantage when outsourcing is being implemented.
- The study recommends that when AB Ltd is already an order winner for some components in the region, those must not be outsourced. In support of this recommendation, the study suggests that no outsourcing should be implemented for parts that will have direct impact on AB Ltd's customers.
- The study recommends that although AB Ltd outsourced to save money at times, it makes it difficult and unusual to ensure that the projected savings tie up with the actuals. In the beginning, the partnership seems to realize savings for the firm, however a few months in the agreement, price adjustments, time loss and other global factors come up. This recommendation emphasis that AB

Ltd should not only focus on cost when practicing outsourcing, but to also consider other factors.

- This recommendation is all about controlling and maintaining the outsourced components. The staff that is responsible to oversee the relationship from various stakeholders need to be skilled. This includes managers, engineers, warehouse supervisors, planners, quality personnel and others. All these stakeholders need to understand the corporate vision well and be able to oversee processes and the part being outsourced.

5.6 Proposals for Future Research

The proposals for future research constructed are presented below:

- Explore and conduct further research at AB Ltd on outsourcing of other activities (marketing, shipping and logistics, IT management and customer services) than production, this might also increase overall company efficiency.
- Further research should be conducted in other regions like western region, inland region, northern region and southern region in AB Ltd in order investigate any gap that might be like the one of this study. The reason for this is that the study only focused on the eastern region located in Kwa-Zulu natal although the company still has other branches in other regions.
- It would be good for AB Ltd nationally to be made aware and informed on gaps related to production outsourcing, hence a bigger sample size would need to be considered for next research studies.

5.7 Limitations of The Study

Limitations do exist for this study. The sample was restricted to only AB Ltd manufacturing facility, in the rolling stock sector located in Durban SA. Even though the study is not a representation of the entire manufacturing rolling stock sector in SA, the findings presented essential information on understanding of production outsourcing influence. This crucial information is mostly important for the Durban region where the study was conducted, but it does not imply that other regions and

researchers cannot make use of it. Another limitation is that the study did not pay additional attention to possible factors that could also affect the efficiency of production like land, capital goods and entrepreneurship (DAMIYANO 2018).

5.8 Conclusion Comments

This study provided conclusions related to the literature review and presented summarized findings. Moreover, it provided recommendations, limitations, future recommendations arising from the findings on production outsourcing influence in the rolling stock manufacturing sector AB Ltd in SA, focusing on the Durban region. This study found that production outsourcing does not necessarily reduce production costs. It also found that production outsourcing has some form of influence in managing and supporting increased customer demands. However, based on the results from the second aspect of the study, it does not bare a positive influence in relation to production costs.

The solutions to high production costs do not lie in production outsourcing for AB Ltd, this is evident based on the findings presented. Even though for AB Ltd the solution for high production costs is not outsourcing, the study did manage to make some recommendations based on the findings. Some of them are to always ensure to outsouce the correct parts, keeping core parts inhosue, and also emphasing that the organisation does not save money by outsourcing.

6. REFERENCES

Abriyantoro, D., Dong, J., Hicks, C. and Singh, S. P. 2019. A stochastic optimisation model for biomass outsourcing in the cement manufacturing industry with production planning constraints. *Energy*, 169: 515-526.

Ali, A., Cao, M., Allen, J., Liu, Q., Ling, Y. and Cheng, L. 2023. Investigation of the drivers of logistics outsourcing in the United Kingdom's pharmaceutical manufacturing industry. *Multimodal Transportation*, 2 (1)

Arnold, U. 2000. New dimensions of outsourcing: a combination of transaction cost economics and the core competencies concept. *European Journal of Purchasing and Supply Management*, 6 (1): 23-29.

Aslam, M. 2021. Chi-square test under indeterminacy: an application using pulse count data. *BMC Med Res Methodol*, 21 (1): 201.

Baily, M. N., Bosworth, B. and Doshi, S. 2020. Productivity comparisons: Lessons from Japan, the United States, and Germany. 39.

Bekithemba, N. 2014. WHAT IS THE FUTURE OF MANUFACTURING IN SOUTH AFRICA? *WHAT IS THE FUTURE OF MANUFACTURING IN SOUTH AFRICA?*: 6.

Bengtsson, L. and Dabhilkar, M. 2008. Manufacturing outsourcing and its effect on plant performance—lessons for KIBS outsourcing. *Journal of Evolutionary Economics*, 19 (2): 231-257.

Bond, J. 2014. Reshoring likely to radically reshape U.S. economy in next 12 months. 69(1): 9.

Carsten Ellwein, A. E., Marcel Vollmer, Oliver Riedel. 2020. Connected production planning and control systems – implementation and the optimization process for subcontracting. *Connected production planning and control systems – implementation and the optimization process for subcontracting*: 196.

Castillo, R. C. 2014. Research-Methodology-Guidelines. *RESEARCH METHODOLOGY GUIDELINES*: 13.

Cheshmberah, M. and Nabavi, S. M. M. 2014. An application of Six Sigma DMAIC methodology in outsourcing management process improvement. *Uncertain Supply Chain Management*, 2 (3): 115-115 - 124.

Choi, J. J., Ju, M., Trigeorgis, L. and Zhang, X. T. 2021. Outsourcing flexibility under financial constraints. *Journal of Corporate Finance*, 67

Chryssolouris, G. 2006. *theory and practice, 2nd edition. Springer -Verlag: New York.* .

Chryssolouris, G., Mavrikios, D. and Mourtzis, D. 2013. Manufacturing Systems: Skills & Competencies for the Future. *Procedia CIRP*, 7: 17-24.

Chryssolouris, G., Mavrikios, D., Papakostas, N., Mourtzis*, D., Michalos, G., and Georgoulias, K. 2008. Digital manufacturing: history, perspectives, and outlook.

Coyle, J. J. 2017. *Supply chain management: a logistics perspective*. Tenth ed. Boston, Mass: Cengage Learning.

Craig, A., Lacity, M. C. and Willcocks, L. P. 2014. South Africa's business process outsourcing services sector : lessons for Western-based client firms. 45(4): 45-58.

Dahlgrün, P. W. and Bausch, A. 2019. How Opportunistic Culture Affects Financial Performance in Outsourcing Relationships: A Meta-Analysis. *Journal of International Management*, 25 (1): 81-100.

DAMIYANO, D. 2018. ANALYSIS OF THE EFFICIENCY LEVELS OF THE MANUFACTURING SECTOR IN ZIMBABWE. 373.

Ellram, L. and Billington, C. 2001. Purchasing Leverage Considerations in the Outsourcing Decision* 1. *European Journal of Purchasing & Supply Management*, 7: 15-27.

Etikan, I. 2017. Sampling and Sampling Methods. *Biometrics & Biostatistics International Journal*, 5 (6)

Fowler, S. B. and Lapp, V. 2019. Sample size in quantitative research: Sample size will affect the significance of your research. *American Nurse Today*, 14 (5): 61-61-62.

G. Chryssolouris, D. M., N. Papakostas, D. Mourtzis. 2006. EDUCATION IN MANUFACTURING TECHNOLOGY AND SCIENCE: A VIEW ON FUTURE CHALLENGES AND GOALS. *EDUCATION IN MANUFACTURING TECHNOLOGY AND SCIENCE: A VIEW ON FUTURE CHALLENGES AND GOALS*: 4.

Hagerty, J. R. W. 2012. Remade in the USA; Once Made in China: Jobs Trickle Back to U.S. Plants. *Remade in the USA; Once Made in China: Jobs Trickle Back to U.S. Plants*: 6.

Janet Toland, P. Y. 2011. An_Exploration_Of_Historical_Methods_For_Information. 15.

Justin Goodwin, M. W. and Mirghani Ibnoaf, M. K., and Hong Yan 2006. APPROACHES TO DATA COLLECTION. 24.

Kandil, N., Hammami, R. and Battaïa, O. 2022. Insourcing versus outsourcing decision under environmental considerations and different contract arrangements. *International Journal of Production Economics*, 253

Kenyon, G. N., Meixell, M. J. and Westfall, P. H. 2016. Production outsourcing and operational performance: An empirical study using secondary data. *International Journal of Production Economics*, 171: 336-349.

Khademi, A. 2015. Statistical Hypothesis Testing withSASandR. *Journal of Statistical Software*, 68 (Book Review 2)

Kotabe, M., Murray, J. Y. and Mol, M. J. 2008. Global sourcing strategy and performance: A “fit” versus “balance” perspective. In: *International Business Scholarship: AIB Fellows on the First 50 Years and Beyond*. 259-277.

Lahiri, S., Karna, A., Chittaranjan Kalubandi, S. and Edacherian, S. 2022. Performance implications of outsourcing: A meta-analysis. *Journal of Business Research*, 139: 1303-1316.

Lane, D. M. 2019. INTRODUCTION TO STATISTICS. 56.

Liu, S., Wang, L. and Huang, W. 2017. Effects of process and outcome controls on business process outsourcing performance: Moderating roles of vendor and client capability risks. *European Journal of Operational Research*, 260 (3): 1115-1128.

M. Yousof, H., Al-nefaie, A. H., Aidi, K., Ali, M. M. and Mohamed, M. i. 2021. A Modified Chi-square Type Test for Distributional Validity with Applications to Right Censored Reliability and Medical Data. *Pakistan Journal of Statistics and Operation Research*: 1113-1121.

Magagula, M. 2017. The influence of outsourcing the core deliverables on the business performance at Eskom Distribution South Africa.

Mahmoud, M. A. 2015. CLASSIFICATION OF PRODUCTION SYSTEMS. 5.

Mazzola, E., Bruccoleri, M. and Perrone, G. 2019. The curvilinear effect of manufacturing outsourcing and captive-offshoring on firms' innovation: The role of temporal endurance. *International Journal of Production Economics*, 211: 197-210.

McCarthy, I. and Anagnostou, A. 2004. The impact of outsourcing on the transaction costs and boundaries of manufacturing. *International Journal of Production Economics*, 88 (1): 61-71.

Naicker, V. 2017. The adoption of lean manufacturing principles in electronic manufacturing: a case of Altech UEC. 162.

Nikos I. Karacapilidis, C. P. P. 1996. Production planning ad control I textile industry: A case study. *Production planning ad control I textile industry: A case study*: 144.

Norman, G. 2010. Likert scales, levels of measurement and the “laws” of statistics. *Advances in health sciences education : theory and practice*, 15 (5): 625-632.

Onesime, M., Yang, Z. and Dai, Q. 2021. Genomic Island Prediction via Chi-Square Test and Random Forest Algorithm. *Computational & Mathematical Methods in Medicine*: 1-1-9.

Pani, A., Mishra, S. and Sahu, P. 2022. Developing multi-vehicle freight trip generation models quantifying the relationship between logistics outsourcing and insourcing decisions. *Transportation Research Part E: Logistics and Transportation Review*, 159

Paul, R. P., Thakar, V. K. and Patel, H. 2021. CHI-SQUARE STATISTICS BASED STATE ESTIMATION OF STOCHASTIC HYBRID SYSTEM WITH MISSING MEASUREMENTS. *Reliability: Theory & Applications*, 60: 287-287-294.

Shekhat, V. M. 2016. Engineering Economics 2. Theory of Production. 17.

Shen, C., Panda, S. and Vogelstein, J. T. 2021. The Chi-Square Test of Distance Correlation. *Journal of Computational and Graphical Statistics*, 31 (1): 254-262.

Valiyattoor, V. and Bhandari, A. K. 2020. Outsourcing and firm performance nexus: An analysis using the conventional and panel double-bootstrap procedure. *Research in International Business and Finance*, 54

Walker, B. F. 1995. The Chi square test: an introduction. 5.

Walker, W. 1993. National Innovation Systems: Britain". In Nelson, R. (ed.). National Innovation Systems: a comparative analysis. New York: Oxford University Press.

Westkamper, E. 2007. Strategic development of factories under the influence of emergent technologies. 422.

Yin, R. 2016 *"Concept and theory of Dynamic operation of the Manufacturing Process" in Theory and Methods of Metallurgical Process Intergration.*

Yousof, H., Aidi, K., Hamedani, G. G. and Mohamed, I. 2021. A new parametric lifetime model with modified chi-square type test for right censored validation, characterizations and different estimation methods. *Pakistan Journal of Statistics and Operation Research*: 399-425.

Zhu, W., Ng, S. C. H., Wang, Z. and Zhao, X. 2017. The role of outsourcing management process in improving the effectiveness of logistics outsourcing. *International Journal of Production Economics*, 188: 29-40.

7. APPENDICES

Appendix 1: Sample of outsourced and insourced parts with costs

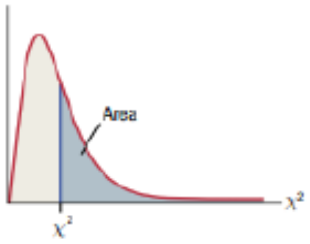
MAT NO.	Material Description	Unit of Measure (UOM)	Insource Cost (IC)	Entry Date	Outsource Cost (OC)	Entry Date
0000001	NUT ROUND;M32,METRIC,2 TPI,STL,HT:43	EA	R 154.51	14-12-20	R 144.76	04-02-20
0000002	SUPPORT;MID TRANSOM ,BT-SA BOGIE	EA	R 4,529.64	14-01-20	R 6,000.00	12-06-19
0000003	SUPPORT;PIVOT TRANSOM,BT-SA BOGIE	EA	R 3,239.59	14-01-20	R 6,350.00	05-08-19
0000004	BOLSTER;BOGIE,SARCAST W1/W2 WAGON,CS	EA	R 7,643.16	29-07-20	R 6,051.48	25-02-20
0000005	CUT, COMP;MK 7 SUBFRAME	EA	R 5,456.34	08-03-19	R 5,585.21	20-03-19
0000006	STRAP RETAINING;BRAKE BEAM,BUNDLE 10	EA	R 86.74	14-01-19	R 96.36	24-11-20
0000007	ADAPTOR D TYPE BEARING UNIT SG	EA	R 420.29	22-01-20	R 430.36	15-07-20
0000008	BOLSTER SPOORBABER	EA	R 6,711.82	05-07-19	R 6,400.14	18-03-20
0000009	SPRING;STABILIZER,STL BLACK	EA	R 432.91	07-08-19	R 432.91	26-08-19
0000010	ADAPTOR;SUBFRAME HS MK7-8,BOGIE	EA	R 25,283.88	09-03-20	R 25,206.02	09-03-20
0000011	WEDGE RAILWAY BEARING;ADAPTOR,SUBFRAME	EA	R 30.18	25-02-19	R 30.18	13-02-19
0000012	ADAPTOR D TYPE AP BEARING BOGIE MK7	EA	R 686.00	11-04-19	R 773.95	11-08-20
0000013	BEAM BRAKE 32 LEVER PIN ASSY MK 7	EA	R 6,618.69	08-12-20	R 6,618.69	04-12-20
0000014	SPRING;STABILIZER,DIA 14 X OD 78 MM	EA	R 486.96	20-11-19	R 486.96	15-11-19
0000015	SPRING HELICAL COMPR;OD:81 MM,STL BLACK	EA	R 436.32	27-08-20	R 436.33	22-09-20
0000016	SPRING;STABILIZER,SPRING STL OIL TEMPRD	EA	R 508.81	30-01-20	R 508.81	02-12-19
0000017	SPRING HELICAL COMPR;OD:82 MM,STL,INNER	EA	R 398.01	16-07-19	R 398.01	27-08-19
0000018	PLATE METAL;HORNFRAME U PIECE,16 MM,STL	EA	R 853.75	20-05-19	R 1,008.19	06-05-19
0000019	ASSEMBLY;MOUNT BEAM,JUMBO WAGON	EA	R 4,494.84	09-12-20	R 4,494.84	26-11-20
0000020	SUPPORT;BRACKET BOGIE FRAME WELD	EA	R 818.25	27-11-19	R 920.00	03-07-19
0000021	SUPPORT;YAW DAMPER,BT-SA BOGIE	EA	R 1,733.07	01-10-19	R 1,720.00	21-06-19
0000022	BOLSTER;BOGIE,SARCAST W1/W2 WAGON,CS	EA	R 5,920.28	30-01-19	R 6,051.48	25-02-20
0000023	SPRING HELICAL COMPR;138 MM,STL,ID:26 MM	EA	R 632.75	31-10-19	R 632.75	15-11-19
0000024	FLANGE GROOVED AIR BRAKES 32mm GROOVED	EA	R 78.98	23-10-20	R 73.18	24-02-20
0000025	FLANGE AIR BRAKE PIPE 20mm GROOVE	EA	R 74.91	05-11-20	R 69.11	20-11-19
0000026	LINK ACTUATING BRAKE;ADJ	EA	R 293.75	03-12-20	R 426.74	12-06-19
0000027	HOLDER CARD-LABEL;WAGON,STL,SIL,GALV	EA	R 244.24	28-02-19	R 259.26	17-09-19
0000028	LEVER;COUPLER RELEASE,STL,WAGON	EA	R 581.16	28-10-20	R 581.16	23-07-20
0000029	HANDLE;COMMODE,LG 570 X THK 25 MM	EA	R 124.37	19-06-20	R 115.83	17-10-19
0000030	PLATE WEAR;BOGIE,ROQ-LAST TH400,RECT	EA	R 43.45	25-06-19	R 40.69	07-02-19
0000031	BRACKET MOUNT;SUPRT,U/FRAME WAGON	EA	R 225.39	08-02-19	R 225.39	04-02-19
0000032	PLATE MOUNTING;REAR BASE,STL HARDOX 500	EA	R 13,089.80	12-07-19	R 13,089.80	29-08-19
0000033	PLATE MOUNTING;FRONT BASE,STL HARDOX 500	EA	R 12,932.20	11-09-19	R 12,932.20	15-07-19
0000034	STOP;CONTAINER DOORS LH,STL,SSHR-1 WAGON	EA	R 3,363.93	02-03-20	R 4,152.25	22-09-20
0000035	LEVER MANUAL CONTROL;RELEASE ROD,STL	EA	R 276.79	26-02-20	R 276.79	25-11-19
0000036	FLANGE ONLY SWIVEL FLANGE 32	EA	R 99.37	02-11-20	R 99.37	07-02-19
0000037	PAD;PUSHER SUPRT PLATE RH,SS GR 3CR12	EA	R 662.01	29-05-19	R 662.01	24-06-20
0000038	BEND, COMP;PLATES,STL	EA	R 135.44	16-09-19	R 135.44	17-08-19
0000039	CUT, MATERIAL;VARIOUS,LASER	EA	R 330.67	15-05-19	R 355.99	05-09-19
0000040	STOP MECHANICAL;BACK COMPOSITE BOX,RECT	EA	R 2,400.00	09-07-20	R 3,723.26	02-12-20
0000041	CHANNEL STRUCTURAL;U,WD:300 MM,HT:100 MM RH	EA	R 3,837.80	23-05-19	R 4,330.97	10-12-20
0000042	CHANNEL STRUCTURAL;U,WD:300 MM,HT:100 MM LH	EA	R 4,019.55	26-02-20	R 4,330.97	01-10-20

Appendix 2: Survey questionnaire responses detail

Timestamp	Emplyee #	1. Production outsourcing is a good practise in the organization.	2. Customers are happy with quality of outsourced parts and assemblies.	3. There is benefits from production outsourcing.	4. It is better to outsource than to produce in-house.	5. Outsourcing is not expensive compared to in-sourcing.	6. Lead times are within desired time for outsourced components.	7. Management does not like to outsourcing unnecessary.	8. The organization should not stop outsourcing.	9. Outsourcing does not take away people's jobs in the organization.	10. When outsourcing is done, production targets are met.	11. Customers are happy all because of outsourcing at times.
6-24-2021 12:28:19	1	2	4	2	1	1	2	1	3	1	4	4
6-23-2021 8:09:08	2	1	1	2	1	1	1	5	1	1	1	2
6-23-2021 8:11:42	3	3	2	2	1	1	2	4	3	2	2	2
6-23-2021 8:21:38	4	1	4	1	1	1	2	3	1	1	1	1
6-23-2021 8:53:57	5	3	3	3	3	3	3	5	2	1	3	1
6-23-2021 13:33:21	6	1	1	1	1	1	1	5	1	1	1	1
6-23-2021 13:42:45	7	2	2	4	1	2	3	1	1	1	2	3
6-23-2021 14:23:44	8	4	4	4	1	5	5	5	4	3	4	4
6-23-2021 14:45:29	9	4	3	3	3	3	3	3	4	3	3	3
6-23-2021 14:59:14	10	3	3	4	4	4	3	2	3	5	3	3
6-24-2021 8:00:42	11	1	1	1	1	1	1	1	5	5	1	1
6-24-2021 8:05:04	12	5	3	5	3	3	2	5	4	4	4	3
6-24-2021 8:19:49	13	3	4	3	2	2	2	4	2	2	3	2
6-24-2021 12:01:11	14	1	1	1	1	3	5	5	5	1	4	4
6-24-2021 12:35:37	15	1	2	1	1	1	4	5	1	1	3	4
6-24-2021 12:36:39	16	2	2	2	1	2	2	2	1	2	2	2
6-24-2021 12:41:48	17	1	3	3	1	1	1	3	5	1	2	2
6-24-2021 12:46:35	18	1	3	3	1	1	3	4	1	1	3	3
6-24-2021 12:46:41	19	3	3	3	5	3	3	3	2	4	3	3
6-24-2021 13:51:52	20	2	2	2	1	2	2	5	2	1	3	3
6-24-2021 13:56:20	21	1	2	1	1	1	2	5	1	1	2	2
6-25-2021 7:29:13	22	4	4	4	4	5	4	5	5	5	5	4
6-25-2021 8:14:19	23	3	4	4	3	3	4	4	2	4	3	3
6-25-2021 8:59:21	24	2	4	4	3	2	4	4	4	4	4	4
6-25-2021 9:50:41	25	5	4	4	3	3	4	3	4	2	4	2
6-25-2021 11:16:07	26	2	2	4	2	1	4	5	5	1	4	2
6-25-2021 12:42:57	27	4	3	4	3	2	3	5	3	4	4	3
6-25-2021 13:05:00	28	1	3	3	5	3	4	5	3	2	5	3
6-29-2021 8:01:04	29	5	5	3	2	1	2	2	3	4	3	1
6-29-2021 14:07:29	30	1	1	1	1	1	2	2	5	1	2	2
6-29-2021 14:14:43	31	2	3	5	2	3	4	5	2	1	3	3
6-29-2021 14:17:55	32	3	3	3	1	1	2	3	3	1	3	2
6-29-2021 14:29:51	33	1	2	3	1	2	3	4	1	1	2	2
6-29-2021 14:33:14	34	3	3	3	1	3	3	3	3	3	3	3
6-29-2021 15:46:01	35	3	3	4	1	3	3	4	3	1	3	2
6-30-2021 12:05:08	36	4	4	3	1	1	2	4	2	4	4	4
6-30-2021 12:40:56	37	4	5	4	5	3	4	4	5	5	5	4
6-30-2021 13:39:58	38	1	2	1	5	3	5	5	2	2	3	2
6-30-2021 14:23:24	39	3	4	4	4	4	4	3	4	3	4	4
7-4-2021 9:29:47	40	3	3	3	3	4	4	4	4	3	4	3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
11. Customers are happy all because of outsourcing at times.	4	2	2	1	1	1	3	4	3	3	1	3	2	4	4	2	2	3	3	3	2	4	3	4	2	2	3	3	1	2	3	2	2	3	2	4	4	2	4	3
10. When outsourcing is done, production targets are met.	4	1	2	1	3	1	2	4	3	3	1	4	3	4	3	2	2	3	3	3	2	5	3	4	4	4	4	5	3	2	3	3	2	3	3	4	5	3	4	4
9. Outsourcing does not take away people's jobs in the organization.	1	1	2	1	1	1	1	3	3	5	5	4	2	1	1	2	1	1	4	1	1	5	4	4	2	1	4	2	4	1	1	1	1	3	1	4	5	2	3	3
8. The organization should not stop outsourcing.	3	1	3	1	2	1	1	4	4	3	5	4	2	5	1	1	5	1	2	2	1	5	2	4	4	5	3	3	3	5	2	3	1	3	3	2	5	2	4	4
7. Management does not like to outsourcing unnecessary.	1	5	4	3	5	5	1	5	3	2	1	5	4	5	5	2	3	4	3	5	5	5	4	4	3	5	5	5	2	2	5	3	4	3	4	4	4	5	3	4
6. Lead times are within desired time for outsourced components.	2	1	2	2	3	1	3	5	3	3	1	2	2	5	4	2	1	3	3	2	2	4	4	4	4	4	3	4	2	2	4	2	3	3	3	2	4	5	4	4
5. Outsourcing is not expensive compared to in-sourcing.	1	1	1	1	3	1	2	5	3	4	1	3	2	3	1	2	1	1	3	2	1	5	3	2	3	1	2	3	1	1	3	1	2	3	3	1	3	3	4	4
4. It is better to outsource than to produce in-house.	1	1	1	1	3	1	1	1	3	4	1	3	2	1	1	1	1	1	5	1	1	4	3	3	3	2	3	5	2	1	2	1	1	1	1	1	5	5	4	3
3. There is benefits from production outsourcing.	2	2	2	1	3	1	4	4	3	4	1	5	3	1	1	2	3	3	3	2	1	4	4	4	4	4	4	3	3	1	5	3	3	3	4	3	4	1	4	3
2. Customers are happy with quality of outsourced parts and assemblies.	4	1	2	4	3	1	2	4	3	3	1	3	4	1	2	2	3	3	3	2	2	4	4	4	4	2	3	3	5	1	3	3	2	3	3	4	5	2	4	3
1. Production outsourcing is a good practise in the organization.	2	1	3	1	3	1	2	4	4	3	1	5	3	1	1	2	1	1	3	2	1	4	3	2	5	2	4	1	5	1	2	3	1	3	3	4	4	1	3	3

Appendix 4: Critical value of X^2 table

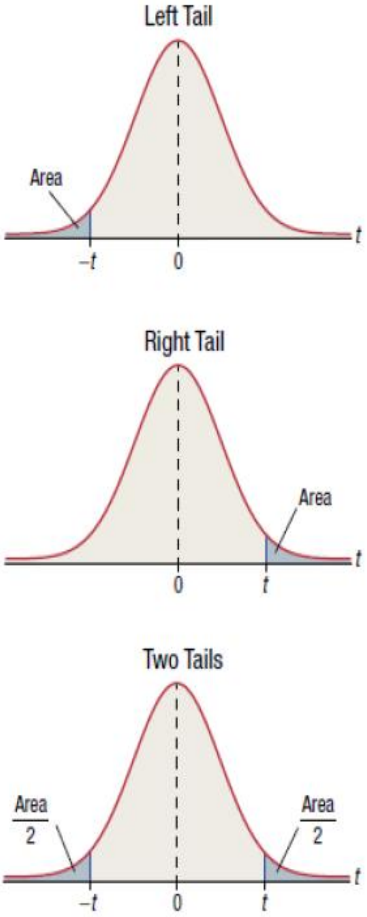


Area to the Right of the Critical Value of χ^2

df	0.995	0.990	0.975	0.950	0.900	0.100	0.050	0.025	0.010	0.005
1	0.000	0.000	0.001	0.004	0.016	2.706	3.841	5.024	6.635	7.879
2	0.010	0.020	0.051	0.103	0.211	4.605	5.991	7.378	9.210	10.597
3	0.072	0.115	0.216	0.352	0.584	6.251	7.815	9.348	11.345	12.838
4	0.207	0.297	0.484	0.711	1.064	7.779	9.488	11.143	13.277	14.860
5	0.412	0.554	0.831	1.145	1.610	9.236	11.070	12.833	15.086	16.750
6	0.676	0.872	1.237	1.635	2.204	10.645	12.592	14.449	16.812	18.548
7	0.989	1.239	1.690	2.167	2.833	12.017	14.067	16.013	18.475	20.278
8	1.344	1.646	2.180	2.733	3.490	13.362	15.507	17.535	20.090	21.955
9	1.735	2.088	2.700	3.325	4.168	14.684	16.919	19.023	21.666	23.589
10	2.156	2.558	3.247	3.940	4.865	15.987	18.307	20.483	23.209	25.188
11	2.603	3.053	3.816	4.575	5.578	17.275	19.675	21.920	24.725	26.757
12	3.074	3.571	4.404	5.226	6.304	18.549	21.026	23.337	26.217	28.300
13	3.565	4.107	5.009	5.892	7.042	19.812	22.362	24.736	27.688	29.819
14	4.075	4.660	5.629	6.571	7.790	21.064	23.685	26.119	29.141	31.319
15	4.601	5.229	6.262	7.261	8.547	22.307	24.996	27.488	30.578	32.801
16	5.142	5.812	6.908	7.962	9.312	23.542	26.296	28.845	32.000	34.267
17	5.697	6.408	7.564	8.672	10.085	24.769	27.587	30.191	33.409	35.718
18	6.265	7.015	8.231	9.390	10.865	25.989	28.869	31.526	34.805	37.156
19	6.844	7.633	8.907	10.117	11.651	27.204	30.144	32.852	36.191	38.582
20	7.434	8.260	9.591	10.851	12.443	28.412	31.410	34.170	37.566	39.997
21	8.034	8.897	10.283	11.591	13.240	29.615	32.671	35.479	38.932	41.401
22	8.643	9.542	10.982	12.338	14.041	30.813	33.924	36.781	40.289	42.796
23	9.260	10.196	11.689	13.091	14.848	32.007	35.172	38.076	41.638	44.181
24	9.886	10.856	12.401	13.848	15.659	33.196	36.415	39.364	42.980	45.559
25	10.520	11.524	13.120	14.611	16.473	34.382	37.652	40.646	44.314	46.928
26	11.160	12.198	13.844	15.379	17.292	35.563	38.885	41.923	45.642	48.290
27	11.808	12.879	14.573	16.151	18.114	36.741	40.113	43.195	46.963	49.645
28	12.461	13.565	15.308	16.928	18.939	37.916	41.337	44.461	48.278	50.993
29	13.121	14.256	16.047	17.708	19.768	39.087	42.557	45.722	49.588	52.336
30	13.787	14.953	16.791	18.493	20.599	40.256	43.773	46.979	50.892	53.672
40	20.707	22.164	24.433	26.509	29.051	51.805	55.758	59.342	63.691	66.766
50	27.991	29.707	32.357	34.764	37.689	63.167	67.505	71.420	76.154	79.490
60	35.534	37.485	40.482	43.188	46.459	74.397	79.082	83.298	88.379	91.952
70	43.275	45.442	48.758	51.739	55.329	85.527	90.531	95.023	100.425	104.215
80	51.172	53.540	57.153	60.391	64.278	96.578	101.879	106.629	112.329	116.321
90	59.196	61.754	65.647	69.126	73.291	107.565	113.145	118.136	124.116	128.299
100	67.328	70.065	74.222	77.929	82.358	118.498	124.342	129.561	135.807	140.169

Appendix 5: Critical value of *t* table

	Area in One Tail				
	0.100	0.050	0.025	0.010	0.005
	Area in Two Tails				
df	0.200	0.100	0.050	0.020	0.010
1	3.078	6.314	12.706	31.821	63.657
2	1.886	2.920	4.303	6.965	9.925
3	1.638	2.353	3.182	4.541	5.841
4	1.533	2.132	2.776	3.747	4.604
5	1.476	2.015	2.571	3.365	4.032
6	1.440	1.943	2.447	3.143	3.707
7	1.415	1.895	2.365	2.998	3.499
8	1.397	1.860	2.306	2.896	3.355
9	1.383	1.833	2.262	2.821	3.250
10	1.372	1.812	2.228	2.764	3.169
11	1.363	1.796	2.201	2.718	3.106
12	1.356	1.782	2.179	2.681	3.055
13	1.350	1.771	2.160	2.650	3.012
14	1.345	1.761	2.145	2.624	2.977
15	1.341	1.753	2.131	2.602	2.947
16	1.337	1.746	2.120	2.583	2.921
17	1.333	1.740	2.110	2.567	2.898
18	1.330	1.734	2.101	2.552	2.878
19	1.328	1.729	2.093	2.539	2.861
20	1.325	1.725	2.086	2.528	2.845
21	1.323	1.721	2.080	2.518	2.831
22	1.321	1.717	2.074	2.508	2.819
23	1.319	1.714	2.069	2.500	2.807
24	1.318	1.711	2.064	2.492	2.797
25	1.316	1.708	2.060	2.485	2.787
26	1.315	1.706	2.056	2.479	2.779
27	1.314	1.703	2.052	2.473	2.771
28	1.313	1.701	2.048	2.467	2.763
29	1.311	1.699	2.045	2.462	2.756
30	1.310	1.697	2.042	2.457	2.750
31	1.309	1.696	2.040	2.453	2.744
32	1.309	1.694	2.037	2.449	2.738
34	1.307	1.691	2.032	2.441	2.728
36	1.306	1.688	2.028	2.434	2.719
38	1.304	1.686	2.024	2.429	2.712



Appendix 5: Critical value of *t* table continued……

40	1.303	1.684	2.021	2.423	2.704
45	1.301	1.679	2.014	2.412	2.690
50	1.299	1.676	2.009	2.403	2.678
55	1.297	1.673	2.004	2.396	2.668
60	1.296	1.671	2.000	2.390	2.660
70	1.294	1.667	1.994	2.381	2.648
80	1.292	1.664	1.990	2.374	2.639
90	1.291	1.662	1.987	2.368	2.632
100	1.290	1.660	1.984	2.364	2.626
120	1.289	1.658	1.980	2.358	2.617
200	1.286	1.653	1.972	2.345	2.601
300	1.284	1.650	1.968	2.339	2.592
400	1.284	1.649	1.966	2.336	2.588
500	1.283	1.648	1.965	2.334	2.586