



A feasibility study of automation in manufacturing processes among scaffold manufacturers

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Mini-dissertation submitted in partial fulfilment of the requirements for the degree *Master of Business Administration* at the North-West University

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Graduation: May 2018
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PREFACE

I would like to express my sincere gratitude to the following people without whom this study would not have been possible:

- To God our Father, for giving me the courage and talent to believe in myself as well as the strength to complete this study.
- Prof J Visagie, for his professional guidance and contributions in completing this dissertation.
- Ms S Ellis for her professional guidance in completing the statistical analysis.
- Ms C van Zyl for the language editing.
- My family, friends and colleagues for enduring the past few years, encouraging and motivating me. Thanks for working with me to achieve this goal.

ABSTRACT

Subject: A feasibility study of automation in manufacturing process among scaffold manufacturers

Keywords: Automation, semi-automation, throughput, scaffolding, scaffold, profitability

This study addresses the implementation of semi-automated and automated manufacturing processes among scaffold manufacturers and the possible benefits associated with them. Scaffolding has become increasingly more popular over the last couple of years and manufacturers within the South African manufacturing market simply cannot keep up with the current demand for scaffold. Therefore, customers must wait longer for their scaffolding to be delivered or they rely on more conventional methods such as building trestles and ladders to perform their jobs, which is a major safety hazard. Due to the always increasing health and safety standards as well as the focus of the mining charter on health and safety it has become inevitable for scaffold manufacturers to expand and/or streamline their operations in order to serve the current demand in the industry. This study aims to compare the throughput as well as the cost effectiveness of both the traditional and automated manufacturing techniques and to determine whether it is feasible to implement semi-automated and/or automated manufacturing processes.

A cycle time study was conducted on both the traditional manufacturing techniques as well as the semi-automated and automated methods. The welders and machine operators were tested in the practical environment. The first test was done in South Africa, where we tested the normal traditional methods of manufacturing, and the second test on the semi-automated and automated methods, was conducted in China and South Africa. With skilled labour and personnel being skilled in the art of welding and machining becoming scarcer by the day, it has become increasingly difficult for scaffold manufacturers to find quality welders and machine operators.

A total of 40 different cycle times were performed on the traditional manufacturing process of a ledger 2 500, and a total number of 20 cycle times were performed on the traditional manufacturing of a hook-on board 2 500. On the semi-automation process to manufacture a ledger 2 500, there were 20 cycle time studies making use of video recordings and manual visualisation, and on the automated roll forming the operation, which is suggested to replace the traditional hook-on board manufacturing techniques, we relied on studies conducted by

the machine manufacturer, visualisation and making use of video recordings. The current remuneration rates as set forth by the MEIBC and the bargaining council were used as the remuneration rate per hour when the cost was calculated.

During this study, it was proved that the factory throughput will indeed increase when you introduce semi-automated and automated manufacturing processes. The introduction of semi-automated and automated manufacturing methods also increased profitability, and freed up valuable skilled workers who can be utilised in other segments of the business.

The limitations of this study are that the numerical tests and the cycle times were only conducted at one scaffold manufacturing plant. Scaffold manufacturing plants tend to keep their manufacturing techniques that are unique to them to themselves and often do not share them with the market. This study can be replicated with regard to the whole scaffold industry, which could be beneficial for the scaffold industry as a whole.

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1 CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Scaffolding and scaffold-related structures have formed part of construction for ages and can be traced back as far as ancient Greece with the building of the Berlin Foundry Cup in the early 5th Century. The sockets in the wall around the Palaeolithic Cave Painting at Lascaux also suggest that a scaffold-like structure was used when they painted the ceilings. The scaffold structures of the past were made from wood or bamboo, which was tied together by ropes. In the early 1930s, Daniel Palmer Jones, who became known as the grandfather of scaffolding, patented the “scaffixer”, which was much more robust than the scaffold systems used at that time. This system was also used in the reconstruction of Buckingham Palace in the early 1900s, where it gained valuable exposure, which led to Palmer-Jones developing the universal coupler system, which soon became the standard for scaffold systems and remains so until this day. (Morton 2008:23)

The basic components of scaffolding consist of tubes, couplers and boards that are both made from steel or aluminium and welded together. The horizontal tube, normally referred to as a ledger, has a diameter of 48.4mm, and the wall thickness of 2.65mm with the vertical tube, normally referred to as a standard, has the same diameter, but the wall thickness is slightly thicker measuring at 3.35mm (SANS, 2011:657) The boards, or hook-on boards as commonly referred to, are made of 2mm thick cold rolled steel sheets that are guillotined and bent into the correct sizes and shapes before the hook-on brackets get welded on. The hook-on boards provide the workers with a flat working platform where they can place their tools and/or work on. Even though wooden and bamboo scaffold structures are ancient and not generally accepted as the scaffold systems used today, they are still the preferred scaffold structures throughout India and Hong Kong (Malm, 2013).

1.2 PROBLEM STATEMENT AND CORE RESEARCH QUESTION

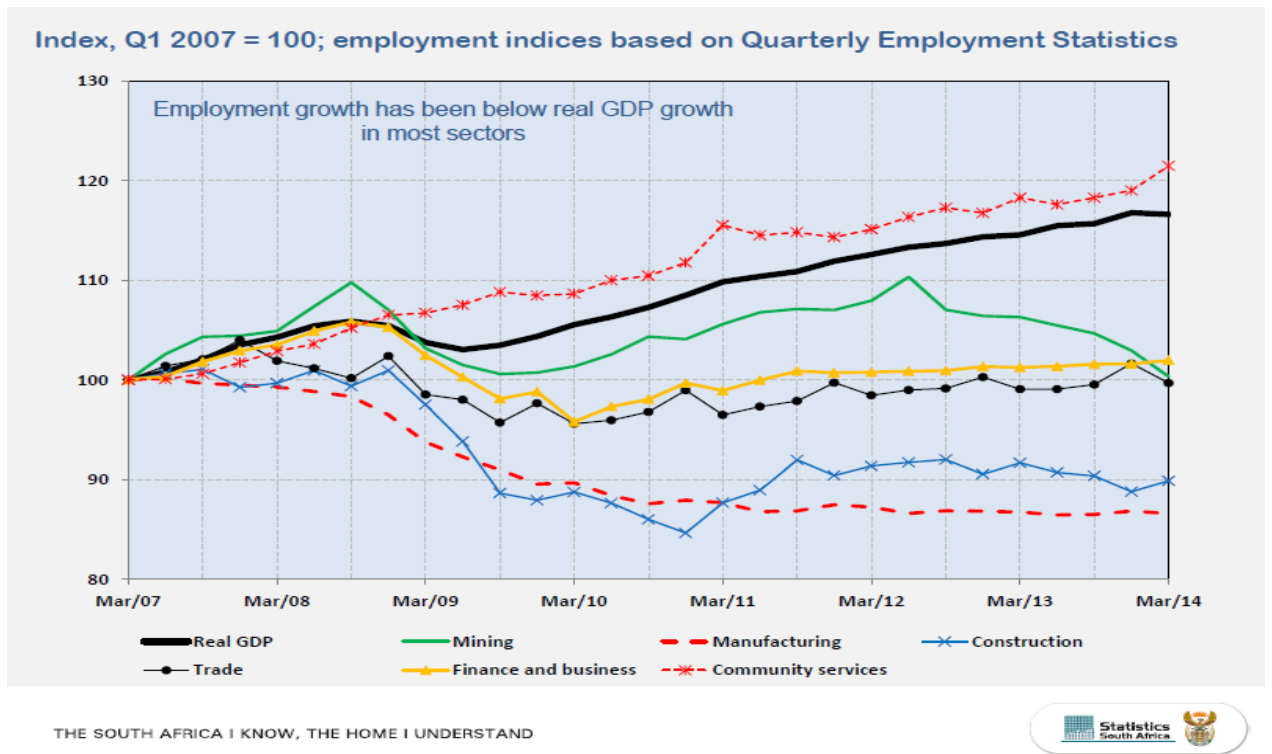
Making use of semi-automated and automated manufacturing processes, the scaffolding industry should aim to achieve a superior quality product delivered to the clients in the shortest time possible.

The traditional methods used to manufacture scaffolding are very labour intensive and consist of various stages of manufacturing, depending on which type of product is manufactured. Because the processes are very labour intensive, it opens the door for different problems, such as bottlenecks in the manufacturing process, longer lead times and larger amounts of rework or scrap items due to human error (Summers & Stevens, 2008:87). The product quality also gets compromised by not only the shortage of skilled labour within the industry, but also the fatigue that sets in as the day progresses (Percio, 2013:35; Stedham, 2007:43; Summers & Stevens, 2008:87; Xue *et al.*, 2005:1134). However, although welding skills take a long time to master and are influenced by numerous factors such as welding speeds, currents and voltage of the welder as well as the welding machine, skilled welders can detect and compromise for all of the above factors by using their basic senses, especially their eyes and ears (Haferkamp *et al.*, 2001:286; Summers & Stevens, 2008:87).

According to the African Construction trends report 2015 published by Deloitte, the construction industry within the African continent has grown year on year. This has put the manufacturing industry of South Africa under tremendous pressure, because, not only have the export markets increased over the same period, but the import market has also decreased (IEconomics, 2016).

All the above influenced the scaffold industry and has put production and manufacturing thereof under immense pressure. The demand for scaffolding has increased along with the increase in the number of construction projects. According to Stats SA, the skilled labour and labourers within South Africa have been stable since 2007 until 2014, but the GDP within the manufacturing industry as well as the construction industry has increased year on year. This has led to a shortage in the number of skilled labourers within the industry.

Figure 1: Employment, unemployment, skills and economic growth



(Statistics South Africa, 2014)

With the implementation of semi-automated production processes, the manufacturing industry could decrease their labour cost per welding process to R38.95 per hour from R89.60 per hour (MEIBC, 2015:2). This will have a cost saving effect of roughly R405.20 per day and R 94 816.80 per year on labour alone, not even mentioning the increase in the production capacity of the plant and the reduced cycle times per product (Summers & Stevens, 2008:87). Implementation hereof will increase both the throughput of the plant as well as the profitability. Semi-automation can also cut the manufacturing cost by reducing welding splatter on the products, and buying the welding wire as well as the CO₂ gas used in the arc-welding process in bulk.

With the extra welder and tacker at your disposal after the implementation of the semi-automated systems, they can be utilised in other processes within the manufacturing process. These labourers will increase the production of labour-intensive production within the factory, where semi-automation and automation are not possible due to welding angles and small welding spaces (Stedham, 2007:43). The optimisation of the production capacity of the manufacturing plant and the

savings of a semi-automated manufacturing process are crucial for the plant to not only stay competitive in the market, but also to keep up with production demands and the increase of profit margins within the industry.

Based on the above theory, the following problem statement could be derived, namely: What will the feasibility for scaffold manufacturers be to use semi-automated systems within their manufacturing processes?

1.3 RESEARCH OBJECTIVES / SPECIFIC RESEARCH QUESTIONS

The specific research objective of this study can be defined as follows:

- To determine whether it is feasible to implement semi-automated and automated manufacturing processes within the scaffold manufacturing industry.

My research objective will be reached by answering the following research questions:

- Have the cycle times and factory throughput improved?
- What is the most cost-effective method within the production process?

1.4 IMPORTANCE AND BENEFITS OF THE PROPOSED STUDY

According to Stats SA, skilled labour and labourers within South Africa have been stable from 2007 until 2014, and the GDP within the manufacturing industry as well as the construction sector has increased year on year, and this has led to a shortage in the number of skilled labourers within the manufacturing industry (Statistics South Africa, 2014). In addition to the scarcity of the skilled labour throughout South Africa, the construction and export markets, according to IEconomics and Trade Economics, throughout the African continent have increased. As the availability of skilled labourers in the market decreases, the demand for high quality products increases (IEconomics, 2016). Industrial and production plants will also face the problem more and more to employ elderly employees in order to satisfy our economic needs in accordance with human factors (Langer & Soffker, 2014:2321). This has become inevitable for the semi-automation and automation of production processes in the scaffold manufacturing industry. This study will illustrate the improvements in the cycle times of the products, the profitability of the market and the decrease in material

handling. It will empower the scaffold industry to make informed decisions regarding automation in the plant and processes.

This study will be focusing on the improvements of the factory throughput, increasing the profitability of the production process and decreasing material handling that normally go along with semi-automated manufacturing processes. If the factory throughput is improved by the usage of the semi-automated process, this will free up some of your skilled workers, addressing the current shortage in the market for skilled workers throughout the industry (Statistics South Africa, 2014). These workers will again improve throughput of other products, and therefore the total factory capacity and the companies' capacity will be increased.

1.5 DELIMITATIONS (SCOPE)

The completed assessment of the potential for semi-automated and automated implementation in some of the scaffold manufacturing operations will be presented during this study. Specifically, time studies of on-site manufacturing processes within the scaffold industry will be used, as well as the gathering of data on semi-automated and automated machinery, which can be imported and used within the South African industry without compromising their quality of workmanship.

Specifically, two cases are evaluated and documented in the study to follow, namely the welding and tacking of a scaffold ledger by using a semi-automated welding machine and the bending and forming of a hook-on board by using a fully automated roll former. The results of this study will be documented with specific reference to the increase/decrease of the production throughput of a manufacturing plant, a decrease in the number of times the materials are handled to reduce fatigue and the growth of profitability if semi-automated and automated procedures are used.

A performance evaluation of the semi-automated and automated manufacturing processes contributes to the most important part of the research outcomes. The study will be relying on data gathered from a machine manufacturer in China that also made use of time and motion studies to collect the data on the semi- and automated machines, and this data will be used in the representation of the semi- and automated

processes. The conclusion of this data will constitute the final part of this study, and it will provide a firm foundation for the feasibility study of these processes.

1.6 ASSUMPTIONS

During my study, the following assumptions will be made:

- The data and video analysis of the machines are accurate. Both of these machines have been physically inspected at the factories in India.
- That the need for access scaffolding will continue soon and that no other access system will be discovered replacing scaffolding in the long run.

The scaffold has been the primary access method within the construction industry throughout the world for many years, and this is likely to continue. Not only does the access scaffolding provide builders with easy, quick and safe access, but it also helps the builders and developers of buildings comply with the strict health and safety regulations as of late.

1.7 DEFINITION OF KEY TERMS

Scaffolding:	According to dictionary.com, scaffolding can be described as “A temporary structure for holding workers and materials during the erection, repair, or decoration of a building”. In this mini-dissertation, scaffolding will be referring to the all the components of the temporary structure, as described above.
Tacker:	According to dictionary.com a Tacker is referred to as “a person that joins something together temporarily”.
Welder (Machine):	A machine used to unite or fuse two or more products together.
Welder (Worker):	A specialist in the use of a welding machine.
Ledger:	According to dictionary.com, a ledger can be described as “a horizontal timber fastened to the vertical uprights of a scaffold, to support the putlogs”, and in this study, a ledger will be referring to the vertical metal/steel tube connected to the scaffold uprights/standards and keeping the scaffold structure in place.
Standard:	The vertical upright of a scaffold structure.
Hook-on board:	The horizontal working platform on which an employee can stand while working or where tools can be placed on. The working

platform will always be connected to a scaffold ledger to form a flat working service.

- Roll former: According to Wikipedia “roll forming, also spelled rollforming, is a type of rolling involving the continuous bending of a long strip of sheet metal into the desired cross-section”.
- Throughput: According to dictionary.com, throughput can be defined as “the amount of material or items passing through a system or process”.
- Automated: An automated system can be described as a device that functions automatically without the continuous inputs of an operator.
- Semi-automated: A partially automated system.
- MEIBC: Metal and Engineering Industries Bargaining Council
- Reworks: In dictionary.com, reworks are described as “making changes to something”; however, in this study, the term will refer to the employee’s mistakes that need to be corrected.
- SANS657-1: South African National Standard – Steel tubes for non-pressure purposes
- SANS10085-1: South African National Standard – The design, erection, use and inspection of access scaffolding

Table 1: Abbreviations used in this document

Abbreviation	Meaning
ZAR	South African Rand
ZA	South Africa
GDP	Gross Domestic Product
SANS	South Africa National Standard
STATS SA	Statistics South Africa
MEIBC	Metal and Engineering Industries Bargaining Council

1.8 DESCRIPTION OF OVERALL RESEARCH DESIGN

This study will follow a quantitative research approach with a quasi-experimental design. According to Bryman *et al.* (2014), quasi-experiments can be described as experiments that attempt to establish cause-effect relationships between variables. A quantitative research approach can be explained as a formal, objective and

numerical process in which numerical data that was collected is being used to obtain information.

This study will generally focus on the implementation of the semi-automated and automated manufacturing process and how, in turn, this implementation will increase scaffold manufacturers' throughput as well as the profitability, quality and consistency of each product that is manufactured. During this study, I will analyse and evaluate, by making use of time studies, the current traditional methods used to make two different scaffolding items, namely a scaffolding ledger and a hook-on board platform.

1.8.1 Time studies

A specific standard can be established by following these eight steps as explained by Heizer and Render (2017):

- a. Define the task to be studied.
- b. Divide the task into precise elements.
- c. Decide how many times to measure the task.
- d. Time and record elemental times and ratings of performance.
- e. Compute the average observed time.
- f. Determine the performance rating and then compute the normal time for each element.
- g. Add the normal time for each item to develop an entire normal time for the task.
- h. Compute the standard time. This adjustment to the total normal time provides for allowances such as personal needs, unavoidable work delays, and worker fatigue.

The task to be studied in this study will be to determine whether it is feasible to implement semi-automated and automated processes within a scaffold manufacturing plant. This will be done by dividing the operations into two elements, namely the time used to handle raw materials and work in progress, as well as the physical time used to perform the welding/tacking procedure in the case of the manufacturing of a scaffolding ledger and the time used to cut, bend and punch the hook-on board platform in the event of the fabrication of a hook-on board platform. For the study to obtain reliable results, each of these time studies will be conducted for a total number of 40 times on three different time slots during the day over a period of two weeks.

1.8.2 Tested numerical data from machine manufacturers

The second set of data that will be used in this study will engage with a contracting firm in India and one contracting firm in South Africa to gather data from them regarding the cycle times of their machines on the various products as tested within South Africa, with particular reference to the elements as documented in the time studies.

All the information that was gathered, as stated above, will be processed and illustrated in an income statement format, from which a conclusion will be presented in the form of a comparison between the throughput quantities, a number of times the material needed to be handled and what the cost of each method of production was. By completing these tests, a conclusion will be reached as to whether the implementation of semi-automated and automated processes is feasible or not.

1.9 POPULATION/SAMPLING

This study will be following a quantitative approach with a correlation research design. The study will compare and analyse two different manufacturing methods within the scaffold manufacturing industry and a number of six to eight participants will be tested.

- a. The first part of the survey data will be gathered through time studies within a scaffold manufacturing plant in Gauteng, South Africa. The specific products that will be tested are:
 - Ledgers 2 500 – Semi-automated welding process
 - Hook-on board 2 500 – Automated roll forming machine

For the ledgers, the following procedure will be followed during the testing stage:

- How long does it take to fetch the raw material and place it in the welding jig?
- How long does it take to tack the product together?
- How long does it take to place the WIP (tacked product) into the WIP bin?
- How long does it take the welder to pick up the WIP product and place it in the welding jig?
- How long does it take for the final welding stage?

- How long does it take to place the final product in the completion bin?
For the hook-on boards, the following procedure will be followed during the testing stage:

- How long does it take to guillotine the product?
- How long does the first bend take?
- How long does the second bend take?
- How long does the third bend take?
- How long does it take to punch the hook-on board?

Because the hook-on board's process is continuous, we will quantify the slowest process and use that time as the basis of this study.

- b. The second part of the survey is to engage with semi-automated and automated machine manufacturers in India and one machine manufacturer in South Africa to gather data from them regarding the cycle times of their machines on the different products as tested within South Africa. Specific reference will be made to the elements tested in the time studies of the traditional methods and a comparison will be made.

The semi-automated ledger machine will be tested in the following manner:

- Picking up and placement of the products in the welding jig will be quantified through videos that were taken of cycle times in India.
- The welding time it takes to finish the welding process of the whole product. (This machine tacks and welds the product in one stage.)

The physical time it takes to remove a finished product and place it in the completion bin. This cycle time was taken through several videos of the time studies by the Indian machine manufacturer.

The automated roll forming machine will be tested in the following manner:

- How long it takes to load the full coil on the de-coiler per forklift. (This data will be supplied by the machine manufacturing firm, and an average will be used between the various companies that supplied the information.)
- How long the entire process takes, from the start of the process until the final product is dropped into the completion bin, which includes running meters per minute covered by the machine.
- All the information that was gathered as stated above will be processed and illustrated in an income statement format out of which a conclusion will be

presented in the form of a comparison between the throughput quantities, the number of times the material needed to be handled and what the cost of each method of production was. By completing these tests, a conclusion will be reached as to whether the implementation of semi-automated and automated processes is feasible or not.

1.10 DATA COLLECTION

1.10.1 Validity

Validity can be defined as how well a test measures what it purported to measure. There are at least three types of validity evidence and for a researcher to gather information, he/she should establish all three validities of the instrument. The three validities that should be created can be defined as follows:

- a. Construct validity refers to whether the examination/evaluator can draw inferences about the time cycles related to the subject matter as studied within this study. There are three sources of construct validity, namely:
 - Homogeneity is the measurement of one single construct.
 - Convergence is when the instruments measure concepts such as that of other constructs and instruments.
 - Theory: When the test behaves according to the theoretical expectations.
- b. Criterion validity refers to any other instruments that measure the same/similar variables. There are three types of criterion validities, namely:
 - Convergent validity has high correlations with measurements of similar variables.
 - Divergent validity has low correlations with measurements of different variables.
 - Predictive validity has high correlations with measurements of the future.
- c. Content validity refers to the sampling of the entire domain of the construct for which it was developed to measure.

1.10.2 Reliability

Reliability relates to the consistency of the test that was done during this study. One can distinguish between three attributes of reliability as well as how it can be tested.

- Homogeneity (or internal consistency) can be described as the extent to which all the items on a scale measure a construct.
- Stability refers to the consistency when using the same instrument in repetitive tests.
- Equivalence refers to the consistency among multiple users of an instrument.

1.10.3 Method used to collect the data

Within this study, the author will be collecting the data by using two different methods, namely:

- Testing the traditional methods of manufacturing within the industry for which time studies will be used to measure the physical production time of each of the items. This process will be done as per the document in Appendix A. The data collection sheet will be divided into different elements as shown in Appendix A.
- For the new and proposed data, the data that the contracting firms have provided and made available for the study will be used.

This data will be collected and converted into cost reports to determine whether it is feasible or not to implement the semi-automated and/or automated systems within the manufacturing processes. This data will form part of profit and loss statements for both processes, and then a conclusion will be drawn based on the results of the processed data.

1.11 DATA ANALYSIS

- Within the first part of the study, the physical data that will be collected from a manufacturing plant in Pretoria, South Africa and the sample size consist of:
 - Two welders and two tackers during the day shift (two teams) and;
 - Two welders and two tackers during the night shift (two teams)

All four teams will be tested over different time periods that will be divided into three sections, namely morning, midday and afternoon for the day shift and evening, midnight and early morning for the night shift. In each timeframe, five to seven cycle times will be conducted and tested.

- With the second part of this study (comparative figures for the semi-automated and automated processes), the author will be relying on data from two independent contracting firms that will be manufacturing the machine in India, China and one machine manufacturer within South Africa.

The author believes that sampling is the best possible unit of analysis because he/she will be using time studies as a measurement. Time studies can only be taken physically, and this study cannot be tested/proven in any other way. By using time studies, a comparison can be reached between the different results found in the traditional method and the semi-automated/automated processes, and in this manner, the study can conclude whether it is feasible or not to use semi-automation within the production processes. Although sampling will be the best unit of historical analysis, data can also be used as a unit of analysis. Research has been conducted to search for possible studies regarding semi-automation and automation within the scaffold industry; however, there is not a great deal data available about this field of study. There is, however, significantly more data available on semi-automation within the manufacturing industry, and this data can be incorporated into this study to a certain extent. Other methods, namely surveys and experimental research studies, will not be able to prove whether semi-automation is feasible or not.

1.12 ASSESSING AND DEMONSTRATING THE QUALITY AND RIGOUR OF THE PROPOSED RESEARCH DESIGN

The research conducted in this study will be quantitative in nature. Quantitative methods can be explained as methods that emphasise objective measurements and the collection of data through mathematical, statistical or numerical analysis. Quantitative research also focuses on the gathering of numerical data to explain a phenomenon. In this study, the author will be gathering different time studies and cycle times from various employees at different time intervals and he/she will be analysing that data to find a conclusion as to whether semi-automation within the scaffold industry is feasible or not. All the methods that the author will be using

(sampling) indicate that he will follow a quantitative research approach to conclude the study.

This study will also be longitudinal in nature. Because the study will be investigating and analysing a specific manufacturing method versus a semi-automated process, the survey needs to have different cycle times at various points during the day and week. The traditional method will be tested, where different aspects such as fatigue, sore muscles etc. can be eliminated by obtaining an average cycle time per product over a given period.

The data points will be measured in the following manner:

- Total population: 40 cycle times per ledger that was manufactured and 10 cycle times for the bending and forming process of the hook-on boards.
- The intervals between the cycle times will be a period of two weeks and the timeframes will vary between early morning, after lunch and before closing during the day, and early evening, after midnight and just before their shift ends in the morning.

1.13 STRUCTURE OF THE STUDY

Chapter 1: Introduction

This chapter outlines the background of the study. The problem statement is formulated, and the research objectives, methods and more general information are provided.

Chapter 2: The literature research

Chapter 2 provides the study with the theoretical background. The chapter researches automation, semi-automation as well as time and motion studies.

Chapter 3: Empirical research: Data analysis, findings and discussion

In Chapter 3, the results of the investigation are discussed.

Chapter 4: Recommendations and conclusions

In this chapter, a summary of what the research has found is presented. The findings are discussed specifically in relation to the objectives that were set, and recommendations are made.

2 CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION TO THE MANUFACTURING AND SCAFFOLDING INDUSTRY

2.1.1 Scaffolding industry

Scaffolding and scaffold-related structures have formed part of construction for ages and can be traced back as far as ancient Greece with the building of the Berlin Foundry Cup in the early 5th Century. The sockets in the wall around the Palaeolithic Cave Painting at Lascaux also suggest that scaffold-like structures were used when they painted the ceilings. The scaffold structures of the past were made from wood or bamboo, which was tied together by ropes. In the early 1930s, Daniel Palmer Jones, who became known as the grandfather of scaffolding, patented the “scaffixer”, which was much more robust than the scaffold systems used at that time. This system was also used in the reconstruction of Buckingham Palace in the early 1900s, where it gained valuable exposure, which led to Palmer-Jones developing the universal coupler system, which soon became the standard for scaffold systems and remains so until this day (Morton 2008:23).

SGB (Scaffolding Great Britain), introduced by Daniel Palmer-Jones in 1922, for the tubular steel pipes in the scaffolding industry, replaced the timber poles that were generally accepted within the scaffold industry. This new system or design brought new and improved stability to scaffolding through the standardisation of the design and dimensions. Today, erected scaffolding is covered by the SANS10085-1:2004, which specifies the performance requirements related to the design, erection, use and inspection of access scaffolding in South Africa. SANS 657-1:2011 specifies the performance requirements of the manufacturing processes of scaffolding as well as all the material requirements thereof (SANS10085-1:2004; SANS657-1:2011).

The basic components of scaffolding consist of tubes, couplers and boards that are made from steel or aluminium and welded together. The horizontal tube, normally referred to as a ledger, has a diameter of 48.4mm and a wall thickness of 2.65mm, with the vertical tube, normally referred to as a standard, which has the same diameter, but the wall thickness is slightly thicker measuring at 3.35mm. (SANS, 657-1:2011). The boards, or hook-on board as commonly referred to, are made from 2mm thick cold rolled steel sheets that are guillotined and bent into the correct sizes and

shapes before the hook-on brackets are welded on. The hook-on boards provide the workers with a flat working platform where they can place their tools and/or work on. Even though wooden and bamboo scaffold structures are ancient and not generally accepted as the scaffold systems used today, they are still the preferred scaffold structures throughout India and Hong Kong (Malm, 2013).

2.1.2 Introduction into the manufacturing industry

According to Jovane *et al.* (2008), manufacturing is the backbone of the industrialised society. Manufacturing started during the industrial revolution of the 19th century to cater for the large-scale production of products (Jovane *et al.*, 2008). However, from the start of the industrial revolution, the manufacturing industry has evolved in such a way that the problem that modern society encounters is to produce more products with less material within a shorter time and without an excessive amount of labour (Chryssolouris *et al.*, 2008).

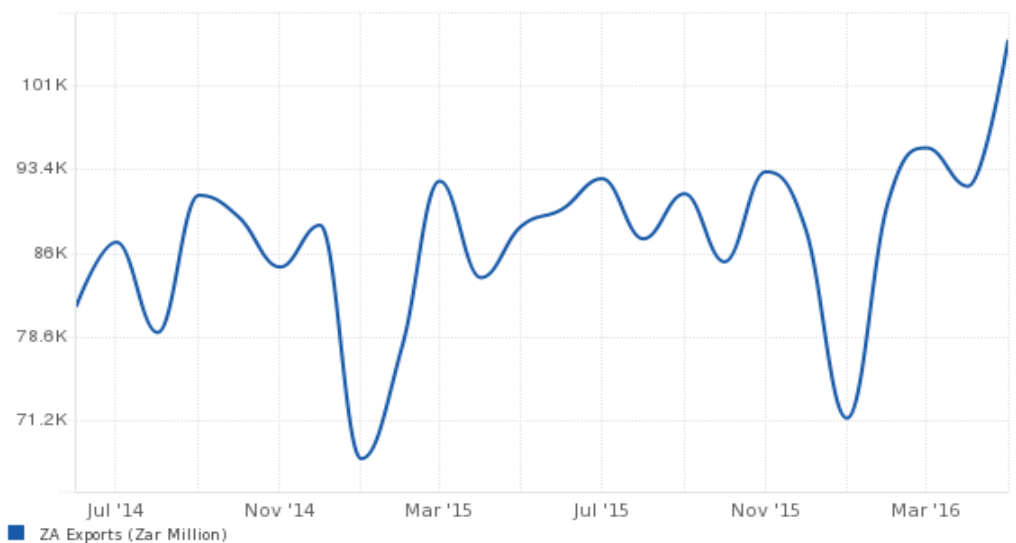
Companies within the manufacturing industry need to focus on developing a goal-based strategy that focuses on the company's individual strengths, to manufacture products of high quality at the lowest cost possible and to deliver their products in the shortest time possible (Esmailian *et al.*, 2016; Balakrishnan *et al.*, 2007; Kost & Zdanowicz, 2005). Each client requires the best product delivered in the shortest time possible at the lowest price. The manufacturing industry can be broken down into three processes, namely high volume, medium volume and low volume processes, with high volume processes consisting of the mass production of items (assembly lines); the medium volume process, which can be described as batch and/or cellular production cells, which are also typically used by the scaffolding industry; and low volume processes, which are normally used by manufacturing companies that specialise in certain products that are complex to manufacture and normally require skilled labourers throughout the manufacturing process.

According to Statistics South Africa, both the construction and manufacturing industries throughout South Africa have grown exponentially since 2011, i.e. 45.85% and 41.12%, respectively (Stats SA, 2014:50-02-01; Stats SA, 2014:30-02-04). This has led to a shortage in the scaffolding manufacturing industry and has forced manufacturers to look at alternatives within the current manufacturing market, which

cannot only address the high demand, but also the shortage of skilled labour within the industry.

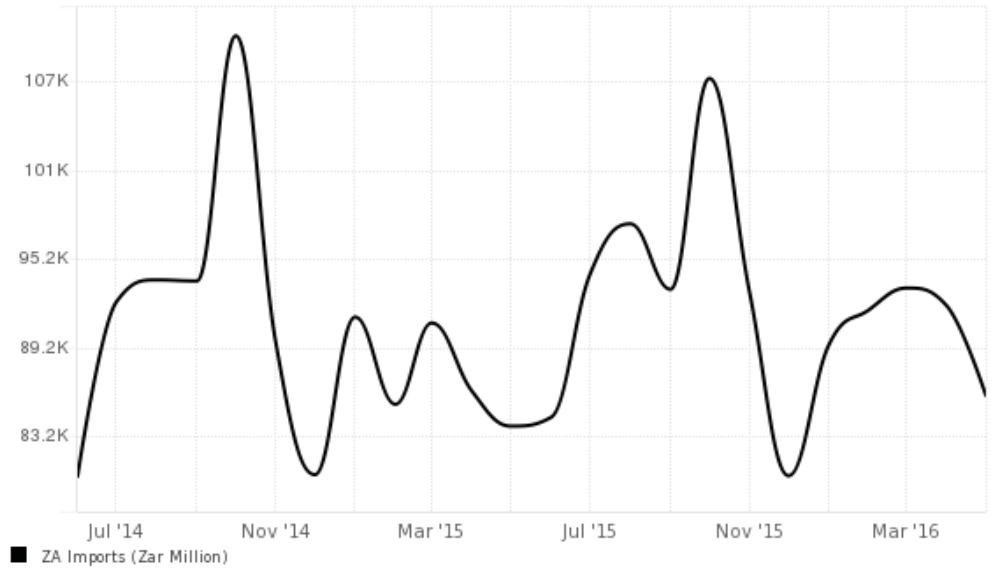
Deloitte also published in the African Construction trends report (2015) that the construction industry has grown within the African continent by 17% to a value of USD 375 billion. This has put the manufacturing industry of South Africa under tremendous pressure due to the rising figure in the export market into Africa. The export market in South Africa has also grown to ZAR 107463.7 million in June 2016 from ZAR 85200 million in October 2015 (ZA exports), according to trade economics. The import of products has decreased to ZAR 85952.7 million in June 2016 from ZAR 107000 million in October 2015 (ZA imports). The decrease in the imports of steel products is due to the import tariff of 10% that was raised on all imported steel by the South African Government in 2015.

Figure 2: ZA exports



(IEconomics (2016))

Figure 3: ZA Imports



(IEconomics (2016))

As shown in the graphs above from IEconomics, it is clearly visible that the imports into South Africa for steel and steel products are decreasing and the export thereof is increasing. This has a direct reflection on the scaffold industry. Larger companies that, in the past, would have rather imported the scaffolding, have started to buy the scaffolding from the South African manufacturers due to high import costs and import taxes that are raised on steel and steel products. The export industry of the steel and steel products, as shown above, has increased in the past two years. The entire African continent is currently expanding and larger developments are happening all over the continent. This has led to the expansion of this market and subsequently increasing the scaffold demand within South Africa.

All the above influenced the scaffold industry and put production and manufacturing thereof under immense pressure. The demand for scaffolding has increased along with the increase in the number of construction projects. According to Stats SA, the skilled labour and labourers within South Africa have been stable since 2007 until 2014, but the GDP within the manufacturing industry as well as the construction industry has increased year on year. This has led to a shortage in the number of skilled labourers within the industry.

2.1.3 Time studies

Time studies involve timing a sample of workers' performance and using it to set a standard for the manufacturing time of a product (Taylor, 1881). The most widely used method is the stopwatch study method, which can be considered as the labour standard method (Heizer & Render, 2014:445-450). According to Heizer and Render (2014), there are eight steps that a trained and experienced person must follow to establish a standard, namely:

- Define the task
- Split the work into different and precise elements
- Decide on the number of measurements
- Record the workers' performance times
- Calculated the average observed time. This is an arithmetic mean of the times of each precise element measured, adjusted for any unforeseen influences on each measurement:

$$\text{Average observed time} = \frac{\text{Sum of the times recorded during measurement}}{\text{Number of measurements}}$$

(Heizer & Render, 2014:445-450)

- Determine the work pace and compute the normal time of each measurement.

$$\text{Normal time} = \text{Average observed time} \times \text{Performance rating factor}$$

(Heizer & Render, 2014:445-450)

The performance rating is somewhat of an art and adjusts the averaged observed time to the times that a trained worker can expect to accomplish.

- Calculate the total normal time for the task.
- Calculate the standard time. Adjustments need to be made to the total normal time for allowances such as:
 - Personal needs,
 - Unavoidable work delays, and
 - Worker fatigue.

$\text{Standard time} = \frac{\text{Total normal time}}{1 - \text{Allowance factor}}$ <p>(Heizer & Render, 2014:445-450)</p>
--

According to Heizer and Render (2014), personal time allowances are often established in the range of 4 to 7% of the total time, depending on the following:

- Distance to the nearest rest room,
- Water fountains, and
- Other facilities.

Delay allowances are based on actual studies, which, in the case of the scaffold manufacturing, can be eliminated. Fatigue allowances, as described by Heizer and Render (2014), are “based on our growing knowledge of human energy expenditure under various physical and environmental conditions.” As explained hereunder, in Figure 4, a sample set of personal and fatigue allowances are set out and shown as percentages of the total time.

Figure 4: Allowance factors (in percentage) for various classes of work

Different allowances		Weight	Fatigue percentages
Constant allowances:	Personal allowance		5%
	Basic fatigue allowance		4%
Variable allowances:	Standing allowance		2%
	Use of muscular energy in lifting	9.07 kg	3%
		18.14 kg	9%

(Heizer & Render, 2014:445-450)

The above figure can be described analysed as follows:

- Personal allowances: Distance to rest room, water fountains and other facilities
- Basic fatigue allowance: Allowance for mental and physical weariness
- Standing allowance: Allowance allocated to the time an employee needs to stand
- Use of muscular energy: Allowance made for energy used during one shift.

The sample size of time studies is also critical to determine just how many cycles should be taken to determine the reliability of the time studies taken. There are specific variables that need to be considered, such as:

- Accuracy required,
- Desired level of confidence, and
- How much the different time studies vary from each other.

Although time studies provide accuracy in setting labour standards, there are two distinctive disadvantages, namely:

- Trained staff need to be employed to ensure accurate analysis
- The tasks need to be performed first before any time studies can be conducted (Heizer & Render, 2014:445-450)

2.2 TRADITIONAL SCAFFOLD MANUFACTURING TECHNIQUES

Traditional/manual manufacturing processes that are largely used throughout the industry are not only very costly, but also make way for human error and other labour constraints (Stedham, 2007:43). By focusing on a labour-intensive process, the industry opens the door for problems such as bottle necks in the manufacturing process, longer lead times for the clients and larger amount of rework or scrap items due to human error (Summers & Stevens, 2008:87). The product quality also gets compromised by not only the shortage of skilled labour in the industry, but also the fatigue that sets in as the day progresses (Stedham, 2007:43; Summers & Stevens, 2008:87; Xue *et al.*, 2005:1134; Percio, 2013:35). However, although welding skills take a long time to master and are influenced by various factors such as welding speeds, currents and voltage of the welder as well as the welding machine, skilled welders can detect and compromise for all of the above factors by using their basic

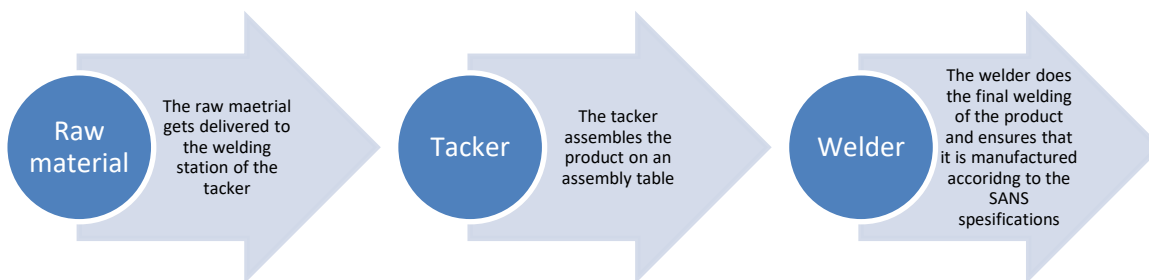
senses, especially their eyes and ears (Summers & Stevens, 2008:87: Haferkamp *et al.*, 2001:286).

2.2.1 Manufacturing of scaffold ledgers

The traditional method used to manufacture scaffolding ledgers consists of two employees working together in a team to complete one item. A team comprises one tacker and one welder and their tasks can be explained as follows:

- Tacker: The tacker receives the raw material and places it inside a forming jig, which is manufactured in accordance with the specific industry standard of each product. The raw material gets tacked into place by the tacker. After the product is assembled, the tacker hands it over to the welder to perform the rest of the assembly.
- Welder: The welder receives the tacked product from the tacker. He is responsible for the final welding of the product in accordance with SANS specifications. After he has finished the weld on the product, it gets sent to the quality inspector and painting department.

Figure 5: Production flow: Traditional ledger manufacturing process



The manufacturing industry of South Africa is regulated by the Metal and Engineering Industries Bargaining Councils (MEIBC) and because the manufacturing falls directly under the steel industry, their wages get pre-determined by the MEIBC. Currently, the MEIBC has a three-year wage negotiation contract in place, which is enforceable by them on all employers. Through these wage amounts that were negotiated by the MEIBC, it is clear that the steel and metals industry has some of the most expensive wage rates in South Africa and that this is not sustainable in the near future.

According to the MEIBC (Metal and Engineering Industries Bargaining Councils), each tacker and welder has a minimum wage of R38.95 and R50.65 per hour, respectively, and therefore the cost per team is R89.60 per hour to complete the scaffolding by means of the ledger manufacturing method (MEIBC 2015:2).

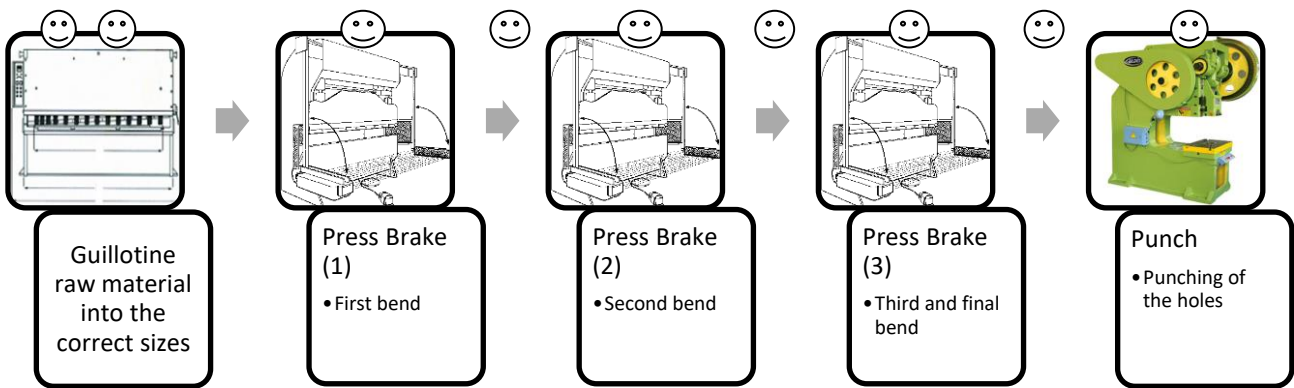
2.2.2 Manufacturing of hook-on boards

The manufacturing of hook-on boards is much more complex and there is a great deal of fabrication that needs to be done before the product is ready to go off to the welding/assembly department. To fabricate hook-on boards, they need to go through the following processes:

- Guillotine raw material into the correct sizes
- First bend
- Second bend
- Third bend
- Punching of holes into the board

The process as explained hereunder in the flow diagram is very labour intensive and the products need to be handled quite often. Each machine has at least one machine operator, and through-out the entire process, there needs to be at least four general workers involved to assist the machine operators with the moving of the raw materials from one station to the next. Since this can be defined as a line manufacturing process, the speed of the manufacturing process will be determined by the slowest portion of the process. As seen in Figure 6 hereunder, the number of employees used throughout the fabrication of one hook-on board is extensive and contributes largely to the overall cost of the product.

Figure 6: Production flow: Traditional hook-on board platform fabrication process



Each team in the manufacturing process, as explained above, consists of five machine operators and four general workers to assist them. Each machine operator has a minimum wage of R38.95 (MEIBC 2015:2) and each general worker R37.04 per hour (MEIBC 2015:2). This accounts for a total team cost of R342.91 per hour to complete the hook-on board fabrication process. The MEIBC controls and regulates all of the labour rates of the employees who fall under the metals and engineering industry, and the labour rates are fixed and pre-determined as per the main agreement of the MEIBC.

2.3 AUTOMATED AND SEMI-AUTOMATED MANUFACTURING TECHNIQUES PROPOSED

The manufacturing industry of today has become more and more competitive, and for any of the manufacturers to stay competitive, they need to deliver the best quality product within the shortest possible time at the lowest price. With the increase in both the construction and manufacturing industry throughout South Africa as well as the growth in the steel product exports into Africa, the scaffold industry has been put under tremendous pressure to supply the market and has struggled to keep up with this

demand. Semi-automated and automated processes have certain advantages, which are explained hereunder:

- Increase in the production throughput,
- Decrease in the direct labour costs and expenses,
- Increase in the consistency and product quality of each process, and
- Decrease in the number of reworks or defective products within a production line.

However, as with every new system implementation, there are certain disadvantages that also need to be considered. The following disadvantages need to be considered, namely;

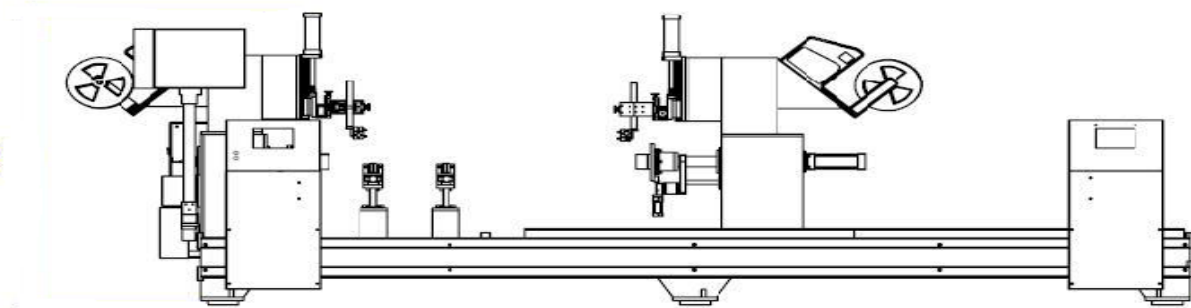
- Job insecurity of employees,
- High initial implementation costs, and
- High development cost of automated systems.

The two manufacturing processes that will be discussed during this study are the manufacturing process of a scaffold ledger as well as the fabrication process of a hook-on board platform. According to Stats SA, the skilled labour and labourers within South Africa have been stable from 2007 until 2014, but the GDP within the manufacturing industry as well as the construction industry has increased on an annual basis. This has led to a shortage in the number of skilled labourers within the industry. The skilled labour shortage within the industry can be addressed through the introduction of automated manufacturing processes, which can at the same time increase the production throughput, decrease the number of reworks within the process, and enhance the consistency of the factory.

2.3.1 Semi-automated manufacturing process for the manufacturing of a scaffold ledger

The semi-automated process that can be used in the manufacturing of a scaffolding ledger will reduce the team used to manufacture each ledger down to just a machine operator who will be operating and feeding the machine with the raw material. The machine, as shown hereunder, will be manufactured and implemented by Sohal Welding Worx from India and is operated by one machine operator earning an amount of R38.95 per hour, according to the MEIBC (MEIBC 2015:2). The operator of this machine will only load the machine with the raw materials and unload the finished product once it has been welded.

Figure 7: Semi-automated ledger welding machine



Using this semi-automated scaffold welding machine, the fatigue that is caused by handling the raw material by the employees is reduced (Percio, 2013:35; Stedham, 2007:43; Summers & Stevens, 2008:87; Xue *et al.*, 2005:1134). This will lead to a higher throughput in the factory because the employees do not need to handle the product as often and he/she will not get as exhausted as before. This product will also address other issues within the manufacturing process, namely:

- Reduce bottlenecks due to human productivity constraints and/or absentees,
 - Reduce lead times of the products and ensure that the company can produce a quality product in a shorter time, and
- Increase the consistency and reduce the number of reworks due to human error (Summers & Stevens 2008:87).

2.3.2 Automated process for the fabrication of a hook-on board platform

According to Paralikas and Salonitis (2011), cold roll forming is a major forming process for the large-scale manufacturing of various complex profiles from a variety of materials and thicknesses and can be classified into the category of sheet metal forming by bending sheet metals into profiles through rotating tools and motions (Chryssolouris, 2005; Lange, 1985). The sheet metal enters the roll forming mill in a coil form and is ultimately formed through consecutive contoured rolls into complex shapes before it is guillotined into the correct sizes. Through roll forming, the factories have been able to produce high volumes of highly accurate products on a constant basis (Chryssolouris, 2005). Through the optimal configuration of the roll forming process, parameters such as the line speed, inter-distance between the roll stations, the roll gap and the size of the rollers can result in a low-cost solution with minimal

product defects and reworks. Not only will the roll forming process improve the product quality, but it will also increase the through-put of the plant by increasing the line speed.

The automated roll forming machine that will be manufactured and implemented by Qingdao High Full International Trade CO., LTD, which is based in China, is a fully automated process that will only require one employee to off-load the fabricated product of the machine. This employee will be classified under the MEIBC Bargaining Council of South Africa as a machine operator and will qualify for a minimum wage of R38.95 per hour (MEIBC 2015:2).

The manufacturer of this machine has specifically manufactured this machine in accordance with the specific requirements as set by the SANS standards of South Africa and the roll forming has been adjusted to meet the demand of the general construction industry throughout Africa and South Africa. By using this machine, the labour costs will be reduced from R342.91 per hour to R38.95 per hour. This will have a tremendous effect on the labour cost of this fabrication process and will reduce the manufacturing costs considerably (MEIBC 2015:2). The automated roll former will consist of the following parts/components:

- De-coiler
- Feeding guide
- Roll forming machine
- Hydraulic guillotine and pump
- Run-out table
- Control box

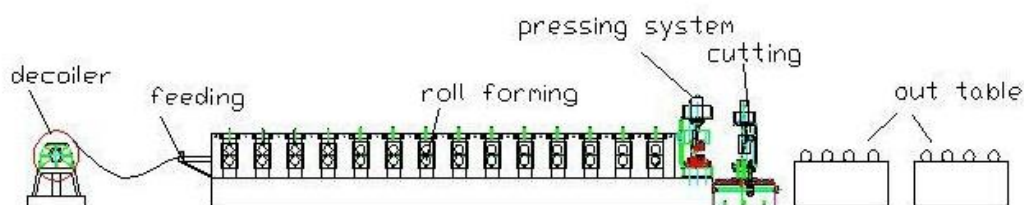


Figure 8: Automated roll forming machine/mill

By implementing this new automated manufacturing process, the author believes that it will not only increase the productivity of the fabrication process, but will also address the following within the industry:

- Help the companies throughout the scaffold manufacturing industry to become more competitive,
- Enable the company to use the skilled machine operators who are no longer required by the implementation thereof on other machines so that they can manufacture some of the components needed, thereby introducing yet another cost saving method into the market,
- Reduce lead times for each customer to the minimum, and
- Increase the quality of products produced and ensure that the quality standard of each product will be consistent.

2.4 THE ESTIMATION OF COSTS AND BENEFITS

One of the most crucial factors to consider during this study is the cost estimation and advantages of semi-automated and automated manufacturing processes. Many factors can be considered, but in this study, the researcher will specifically consider the successful implementation of semi-automated and automated processes within the scaffolding manufacturing industry. These costs and benefits will be determined by analysing the video footage from the machine suppliers in China and India. The videos have been analysed by following a time study method approach and will be compared both through an analysis of the throughput and the cost effectiveness of each method.

2.4.1 Costs

In this study, the author will consider the price associated with the implementation and installation of the semi-automated and automated process as supplied by the two contracting firms. The contracting firms of the machines, as proposed in this mini-dissertation, have specifically developed these machines to comply with the SANS, and other variable factors involved are very difficult to estimate with a satisfactory margin of error. The costs involved can be defined and divided into two categories, namely the capital costs and the operational costs, and can be explained as follows:

- Capital costs

The capital costs are the total costs needed to get the machine operational. These costs mostly consist of the initial cost price of the semi-automated and automated machine, the initial training cost of operational personnel, changes that need to be made to the current factory to support the new machines, special tools that need to be purchased and all other accessories needed.

- Operational costs

The operational costs are all the costs that are incurred while the machine is operational. This cost will be based on similar machines that are currently implemented within the manufacturing industry as well as certain expenses provided by the contracting companies. The operational costs of machines that are currently in use and will form part of the semi-automated and automated process will also be calculated and used in the calculations of the operational costs of the new proposed manufacturing process.

The study will make use of estimates and assumptions based on current data available as well as other similar semi-automated and automated processes within the industry. The conversion cost of the purchase price will be done on the ZAR:-USD exchange rate on the date that the quotation was received from the contracting firms.

2.4.2 Benefits

The benefits from the implementation of semi-automated and automated processes can be derived from the following sources:

- Improvement in work quality

The improvement of the quality will be largely focused on the decrease in the number of reworks throughout the manufacturing process. According to the contracting firm that has designed the semi-automated and automated systems, the number of reworks will be close to zero, if not zero. This assumption will be used throughout this mini-dissertation. The consistency of the manufacturing process and the welding of the products will also contribute to the quality of the product manufactured. Both the automated and the semi-automated machine will deliver products of the same quality as the one before, and this will allow the

manufacturing company to provide the same quality of the product on a continuous basis.

- Labour saving

The labour savings of these processes will be one of the significant contributing factors when considering semi-automated and automated processes within the scaffolding industry. The labour cost saving can be estimated by using the current wages and benefits as received by the machine operators, welders, tackers and general workers that are currently employed to complete the manufacturing process against the estimated employees needed to complete the suggested manufacturing processes.

- Time savings

The assumption made by the author will be based on current automated and semi-automated processes that are implemented throughout the manufacturing industry as well as the information as supplied by the contracting firms about the assumed cycle times for each product. The time savings that will be introduced through the implementation of semi-automated and automated processes will also have monetary benefits because of shorter lead and delivery times.

- Work expansion

The author of this mini-dissertation will assume that the number of employees needed for each semi-automated and automated process, as supplied by the contracting firm, is correct. This will allow the manufacturers within the scaffolding industry to allocate the skilled employees who were replaced by the automated and semi-automated processes to be used in other applications throughout the factory. According to Stats SA, there is a shortage of skilled labourers within the industry, and the industry will benefit tremendously from the expertise of these skilled employees who can now be allocated to a process where their expertise can be utilised accordingly.

3 CHAPTER 3: EMPIRICAL RESEARCH: DATA ANALYSIS, FINDINGS AND DISCUSSIONS

3.1 INTRODUCTION

The purpose of this chapter is to present, discuss and interpret the results obtained from the empirical study. This study attempts to determine the feasibility of automation in the manufacturing processes among scaffold manufacturers through an increase in the factory through-put and an increase in the company profitability when manufacturing a product.

The empirical study was conducted by means of self-observation and time and motion studies at a scaffold manufacturing plant within Gauteng and at the manufacturing plants in China and India. The time and motion studies were conducted in two separate ways:

- Several physical time studies conducted on the traditional manufacturing method in the manufacturing plant in Gauteng,
- Videos were taken of the full manufacturing processes in both India and China and the videos were analysed through Timer Pro to determine the physical time it takes to manufacture one product.

An example of the time studies that were documented is presented in Annexure A.

The mean values, standard deviations and effect sizes were calculated and determined by the Statistical Consultation Services (SCS) of the North-West University, Potchefstroom Campus.

This chapter provides insight into the methods and procedures that were followed to determine the sample size, gathering of data, presentation and discussion of the researched results.

3.2 DATA GATHERING

3.2.1 Development of time and motion studies

The method as suggested by Heizer and Render (2014) was followed to compile and develop the time and motion studies for this study. Heizer and Render (2014) suggested that there are eight steps that a trained and experienced person must follow to obtain and/or establish a standard. In this chapter, the eight different steps will be followed and analysed.

Define the task

The task that required is to determine the full manufacturing time to manufacture one scaffold ledger 2 500 and the fabrication/bending time of one 2 500 hook-on board.

Split the task into different and precise elements

- Ledgers 2 500

Traditional method

- Fetch part from raw material bin and place part in the tacking jig
- Tack part together
- Remove part from tacking jig and place part in WIP bin
- Fetch part from WIP bin and place in welding jig
- Weld part in full
- Place part in finished goods bin

Semi-automated process

- Fetch part from raw material bin and place in welding jig
- Weld part in full
- Place part in finished goods bin

- Hook-on board 2 500

Traditional method

- Do a time study on the following full processes:
 - Guillotining
 - First bend
 - Second bend

Third bend

Punching

- After the time studies were conducted, use the slowest time in the entire system to determine the running meters that the operation can do.

Automated process:

- Determine the running meters per minute through the machine

3.2.2 Sample size

Decide on the number of measurements

The number of the measurements taken was as follows:

- Scaffold Ledger 2 500 (traditional method): 40 time studies
- Scaffold Ledger 2 500 (semi-automated): 10 time studies
- Hook-on board 2 500 (traditional method): 20 time studies
- Hook-on board 2 500 (automated): Constant running rate per meter.

Effect size

The advantages of drawing a random sample are that it enables you to study the properties of a population with the time and money available (Ellis, S.M. & Steyn, H.S. 2003). Many different effect sizes exist (Rosenthal, 1991; Steyn, 1999); however, here we will be focusing on the difference between means for the relationship in two-way frequency tables.

A natural way to comment on practical significance is to use the standardised difference between the means of two populations, thereby dividing the difference between the two means by the estimate for standard deviation. This measure is called effect size, which not only makes the difference independent of units and sample size, but also relates it with the spread of the data (Steyn, 1999; Steyn, 2000).

The test that will be conducted to determine whether the effect sizes are significant or not can be seen hereunder in Figure 13.

Figure 9: Effect size for means

z or t	<p>Population SD's σ_1 and σ_2 not necessarily equal.</p> <p>Take s_{\max} = maximum of s_1 and s_2, the sample SD's.</p>	$d = \frac{ \bar{x}_1 - \bar{x}_2 }{s_{\max}}$
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(Ellis & Steyn, 2003)

Cohen (1988) gives the following guidelines for the interpretation of the effect size in the current case:

- (a) Small effect: $d=0.2$, (b) medium effect: $d=0.5$ and (c) large effect: $d=0.8$.
In this study, we will consider data with $d \geq 0.8$ as practically significant, since it is the result of a difference having a large effect.

Effect size for the relationship in a contingency table

One of the important things to know is the relationship between two variables that are practically significant. For random samples, as in this study, the statistical significance of such relationships is determined with chi-square tests, but the most important aspect to know is whether the relationship is large enough to be important.

In this case, the effect size is given by $w = \sqrt{\frac{X^2}{n}}$, where X^2 is the usual chi-square statistic for the contingency table and n is the sample size (see Steyn, 1999 and Steyn, 2002). In the special case of a 2×2 table, the effect size (w) is given by the phi (ϕ) coefficient. Note that the effect size is again independent of sample size.

Cohen (1988) provides the following guidelines for the interpretation of the effect size in the current case:

- Small effect: $w = 0.1$
- Medium effect: $w = 0.3$
- Large effect: $w = 0.5$

A relationship where $w > 0.5$ is practically significant.

In the ledger 2 500 study, the Cohen's effect size was 8.55, indicating a significant difference in time, and in the hook-on board study, Cohen's effect size was 10.31, indicating that the difference is also significantly important.

3.2.3 Data collection

After the first three steps were followed and completed, the physical time studies started. After two weeks of data collection and obtaining the desired number of measurements, the following results were obtained. The results that were obtained were then reworked to calculate the average observed time, which is the arithmetic mean of the results obtained, adjusted for any unforeseen influences on each measurement. The formula that was used is as follows:

Average observed time = $\frac{\text{Sum of the times recorded during measurement}}{\text{Number of measurements}}$

(Heizer & Render, 2014:445-450)

Ledgers 2 500

Table 2: Physical time studies of ledger 2 500 manufacturing processes

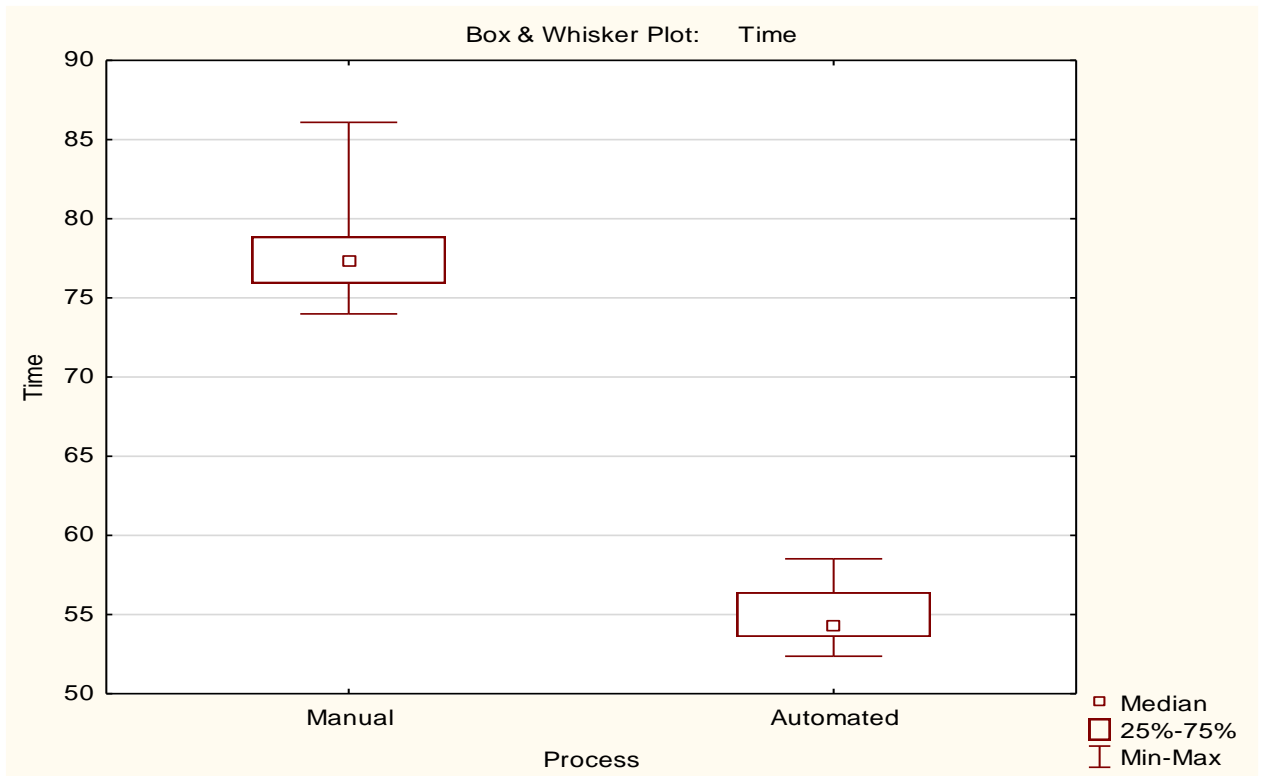
Traditional method		Semi-automated method	
Tasks	Average time	Tasks	Average time
Task 1	18.745s	Task 1	9.856s
Task 2	10.488s	Task 2	37.529s
Task 3	5.820s	Task 3	7.451s
Task 4	4.742s		
Task 5	30.143s		
Task 6	7.793s		

As per Table 2 shown above, the average times of each project were calculated and were found to be as follows:

Traditional method for manufacturing a ledger 2 500: 78.02 seconds

Semi-automated method for manufacturing a ledger 2 500: 55.27 seconds

Figure 10: Mean, median and standard deviation between manual and automated ledger manufacturing processes



(Statistical Consultation Services, North-West University)

- Analysing of results

The manual process had a mean of 77.67 seconds, with the longest manufacturing time being 86.09 seconds and the shortest 74.02 seconds, where the semi-automated process was much faster with a mean of 54.836 seconds, longest manufacturing time of 58.52 seconds and the shortest time of 52.37 seconds. The standard deviation of the manual manufacturing process was calculated at 2.671384 and the semi-automated manufacturing process at 1.926514. The number of studies that were conducted in the manual process and the semi-automated process are 40 and 10, respectively.

Hook-on boards 2 500

To determine the manufacturing rate of the hook-on boards and the current running meters per minute throughput rate, we had to conduct time and motion studies of the current process to determine what process is the slowest and that will be the throughput rate of the bending process. The automated process works on a fixed speed that is regulated.

The time studies, as taken in order to determine the throughput rate of this process, are shown hereunder in Table 3.

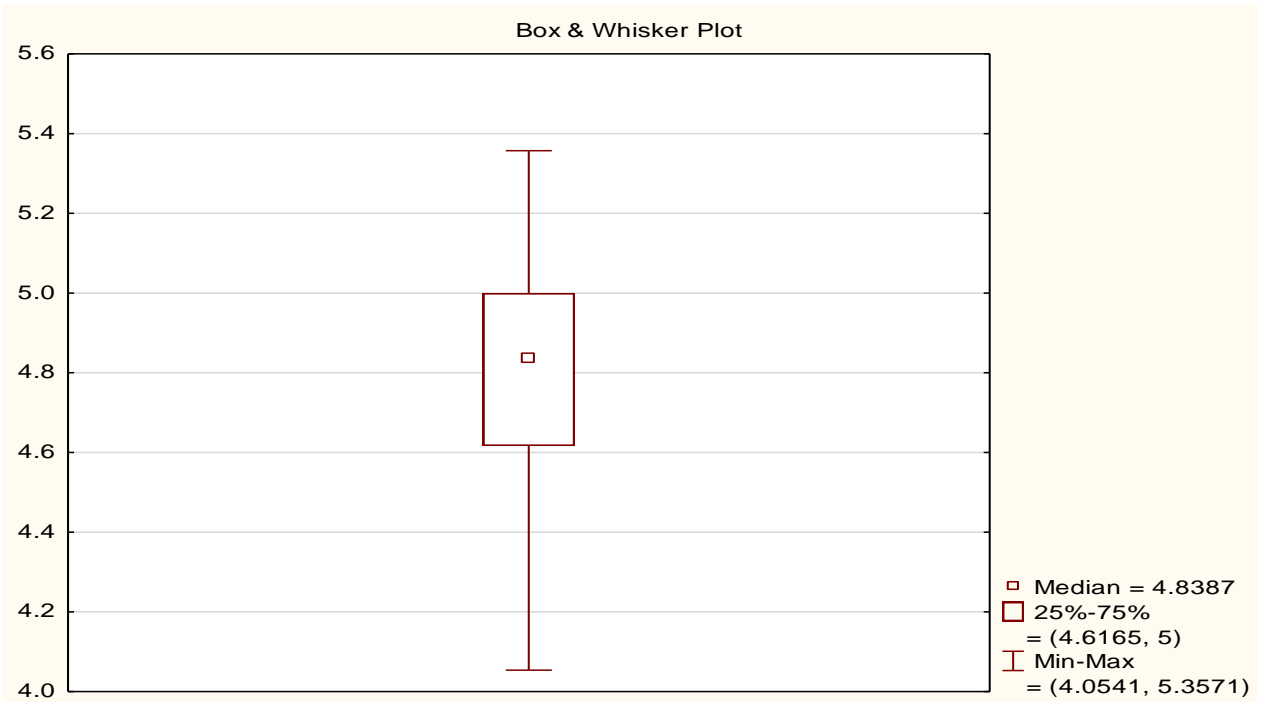
Table 3: Hook-on board time studies

Manual bending/forming process	
Task	Average Time
Guillotining	0.209 seconds
First bend	0.248 seconds
Second bend	0.255 seconds
Third bend	0.312 seconds
Punching	0.270 seconds

The numbers of time and motion studies that were conducted on the hook-on boards' forming and bending process were 20 different studies over a period of two weeks. By doing this, it was clear that the slowest operation in the bending process is the third bend, which takes 0.312 seconds to complete the task. If we calculated the throughput rate of this process, it comes to a running meter per minute of 4.808.

As shown below in Figure 10, the traditional hook-on boards' manufacturing process has a mean of 4.834816 meters per minute and a standard deviation of 0.306545 meters per minute. These time and motion studies were conducted a total of 20 times to ensure that an accurate figure was obtained. During the time studies, the slowest time was 4.054 meters per minute and the quickest was 5.357 meters per minute.

Figure 11: Mean, median and standard deviation of the manual manufacturing processes of hook-on boards 2 500



(Statistical Consultation Services, North-West University)

The automated forming/bending process is a fixed process that has a constant throughput rate of eight meters per minute. This process is automated and no human intervention is required except for the loading and the unloading of the products and/or raw material.

Allowance factors

To calculate the standard time that it takes to manufacture a product, there are several aspects that need to be considered and one of the most important aspects will be the allowances and the allowance factor.

The formula to determine the standard time is as follows:

$$\text{Standard time} = \frac{\text{Total normal time}}{1 - \text{Allowance factor}}$$

(Heizer & Render, 2014:445-450)

The allowance factors were calculated as follows for each of the processes, respectively:

Ledgers 2 500

Figure 12: Allowance factor calculation for ledgers 2 500

Different allowances		Product weight	Fatigue percentage
Constant allowances:	Personal allowance		5%
	Basic fatigue allowance		4%
Variable allowances:	Standing allowance		2%
	Use of muscular energy (>9.07kg)	8kg	3%
Allowance factor for ledgers 2 500			14%

Analysis of allowance factor

The total allowance factor as calculated above states that a factor of 14% needs to be factored into the formula before a standard production time can be calculated. Therefore, to test the study, this allowance factor must be worked into the physical time study taken to ensure that it makes provision for these allowances.

Ledgers 2 500: Traditional manufacturing method

These time studies were conducted in a controlled environment while specialists in their job were performing the duties. This means that there will be no change between the average observed time and the normal time, because it is not necessary to increase the performance rating of anyone that the test has been done on.

To calculate the standard time, the formula as explained above will be implemented and calculated.

$$\begin{aligned}\text{Standard time} &= \frac{78.2 \text{ seconds}}{1 - 14\%} \\ &= \frac{78.2 \text{ seconds}}{0.86} \\ &= 90.93 \text{ seconds}\end{aligned}$$

Ledgers 2 500: Semi-automated manufacturing method

The same formula must be applied to the semi-automated process in order to obtain accurate results.

$$\begin{aligned}\text{Standard time} &= \frac{55.27 \text{ seconds}}{1 - 14\%} \\ &= \frac{55.27 \text{ seconds}}{0.86} \\ &= 64.27 \text{ seconds}\end{aligned}$$

The standard times of both the traditional and semi-automated manufacturing processes are 90.93 seconds and 64.27 seconds, respectively.

Hook-on board 2 500

Figure 13: Allowance factor calculation for hook-on board 2 500

Different allowances		Product weight	Fatigue percentage
Constant allowances:	Personal allowance		5%
	Basic fatigue allowance		4%
Variable allowances:	Standing allowance		2%
	Use of muscular energy (>18.14kg)	13.80kg	9%
Allowance factor for hook-on boards 2 500			20%

As shown in Figure 12 above, this study needs to make provision for the allowance factors as stated. To calculate the new production/manufacturing time of a product, the following formula will be used:

<p>Standard time = $\frac{\text{Total normal time}}{1 - \text{Allowance factor}}$</p> <p>(Heizer & Render, 2014:445-450)</p>
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Hook-on board 2 500: Traditional bending/forming process

The time used to calculate the running meter per minute of the traditional method was the time of the third bend, since it was the slowest part of the operation. The average normal time was 31.27 seconds per product.

If the formula is applied, the following will be achieved:

$$\begin{aligned}\text{Standard time} &= \frac{31.27 \text{ seconds}}{1 - 20\%} \\ &= \frac{31.27 \text{ seconds}}{0.80} \\ &= 39.09 \text{ seconds}\end{aligned}$$

To convert this into running meters, the following needs to be calculated:

$$\begin{aligned}\text{Total running meters} &= \frac{\text{Total length of one Hook-on Board 2500}}{\text{Total time for one Hook-on Board 2500}} \\ &= \frac{2.5\text{meter}}{(0.3909 / 60 \times 100)} \\ &= 3.8372 \text{ meter per minute}\end{aligned}$$

Hook-on board 2 500: Automated bending/forming process

With a machine that is fully automated, fatigue and all other allowances that are of human nature get eliminated and the machine speed and throughput remain the same. Therefore, in the case of the automated forming/bending process of hook-on boards 2 500, the throughput rate will remain eight meters per minute.

3.2.4 Results

Increasing the throughput

Ledgers 2 500: Traditional manufacturing method

$$\begin{aligned}\text{Total throughput} &= \frac{\text{Seconds in one normal day (8hrs)}}{\text{Standard time}} \\ &= \frac{28,800 \text{ seconds}}{90.93 \text{ seconds}} \\ &= 316.727 \text{ units}\end{aligned}$$

Therefore, following the normal traditional manufacturing methods, one can manufacture 316 complete units in an eight-hour working shift.

Ledgers 2500: Semi-automated manufacturing method

$$\begin{aligned} \text{Total throughput} &= \frac{\text{Seconds in one normal day (8hrs)}}{\text{Standard time}} \\ &= \frac{28,800 \text{ seconds}}{64.27 \text{ seconds}} \\ &= 448.110 \text{ units} \end{aligned}$$

Consequently, by making use of the semi-automated manufacturing methods, the total throughput in one day is calculated at 448 units. Overall, it is clear that making and implementing semi-automated manufacturing methods can increase the throughput of the factory by as much as 132 units or 41.772% per day. This makes the implementation of semi-automated manufacturing methods a reality that cannot be ignored.

The price of one ledger 2 500 in July 2015 was R79.05. By introducing the semi-automated manufacturing methods, these machines can increase production and your sales by R10 434.60. This calculates to an annual sales increase of R2 441 696.40 for each machine that is purchased and implemented.

Hook-on board 2 500: Traditional forming/bending method

$$\begin{aligned} \text{Total throughput} &= \text{Minutes per one normal day (8hrs) x running meters per minute} \\ &= 480 \text{ minutes x } 3.8372 \text{ running meters per minute} \\ &= 1\,841.856 \text{ meters per day} \end{aligned}$$

Therefore, taking the above into consideration, it is calculated that by making use of the traditional forming and bending method to bend/form the hook-on board profiles, a number of 736.74 profiles can be made during a normal eight-hour business day.

Hook-on boards 2 500: Automated forming/bending method

$$\begin{aligned}\text{Total throughput} &= \text{Minutes per one normal day (8hrs) x running meters per} \\ &\quad \text{minute} \\ &= 480 \text{ minutes x 8 running meters per minute} \\ &= 3,840 \text{ meters per day}\end{aligned}$$

Therefore, by using the automated method of forming and bending of the hook-on board profiles, it shows that we can form/bend 1 536 profiles in one day, which is an increase of 800 profiles per day or 108.69%. With more than a 100% increase in the factory throughput by means of the implementation of an automated roll former, it is crucial to purchase and introduce the automated roll-forming machine into the manufacturing processes.

Decrease in manufacturing costs

The scaffold manufacturing industry as we know it forms part of the Metals and Engineering Industry Bargaining Council (MEIBC) and its wage rates are prescribed in schedule M of the main agreement. The applicable rates in this study, as set forth by the MEIBC, are as follows:

Rate D:

- Hand welding by mechanically fed electrodes.
- Operating automatic arc and/or gas welding machines (excluding setting up)
- Repetition roller bending and/or forming of plate with pre-set rolls

Rate G

- Operating butt and/or flash and/or projection and/or resistance and/or spot and/or arc spot and/or seam and/or stud welding machine.
- Operating manual machine designed for or permanently adapted for one only operation where it is not necessary to centralise or do the work by hand.
- Attending continuous automatic roller forming machines under instruction of a rate A to D employee

All of these rates, as set forth by the MEIBC, have predetermined hourly rates that need to be taken into account in order to conduct this study. Please refer to Table 4 below for the predetermined hourly rates of all employees employed.

Table 4: Hourly rates

Rate description	Hourly rate for employee
Rate D	R50.65 per hour
Rate G	R38.95 per hour

(MEIBC 2015:2)

Ledger 2500

Traditional method

The traditional method to manufacture one ledger 2500 consists of two processes, namely a tacking and a welding process. The employees who execute these two processes have different skill levels according to the MEIBC and their hourly rates are:

- Tacker: Rate G R38.95
- Welder: Rate D R50.65

The combined rate for the traditional method is R89.60 per hour and the daily rate for an eight-hour shift is R716.80. By making use of the traditional manufacturing method and as per the calculations beforehand, it is safe to say that a number of 316 ledgers can be manufactured during an eight-hour shift.

Therefore, if we look at the total labour cost per product it calculates to R2.27 per product. To calculate the total cost per year when making use of the traditional method the following formula was used:

Total cost	=	Cost per shift	x	Number of shifts
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A fixed number of shifts of 234 shifts as stipulated by the MEIBC's main agreement can be used as the number of shifts that each employee works in a 12-month period.

$$\begin{aligned} \text{Total cost} &= \text{R } 716.80 \quad \times \quad 234 \\ &= \text{R } 167,731.20 \text{ per year} \end{aligned}$$

Semi-automated manufacturing method

The semi-automated manufacturing process is much less labour intensive and consists of only one employee that can be classified in accordance to the MEIBC's job gradings as a Rate G. The cost of this employee is R38.95 per hour and the total hours per day that an employee works remains eight hours per shift.

The number of shifts worked remains 234 shifts during a 12-month period and the same formula is used than above to calculate the total cost.

$$\begin{aligned} \text{Total costs} &= \text{Cost per shift} \quad \times \quad \text{Number of shifts} \\ &= \text{R } 311.60 \quad \times \quad 234 \\ &= \text{R } 72,914.40 \end{aligned}$$

Analysis of results

The cost for the traditional manufacturing methods when manufacturing scaffold ledgers 2 500 had a total throughput of 316 in one shift and a total labour cost of R716.80. This calculated to a total labour cost of R167 731.20 per annum if the traditional methods were used. Through the implementation of the semi-automated manufacturing methods, the labour cost can be reduced to R311.60 per shift and a total of R72 914.40 per annum. This is a decrease in the labour cost of R94 816.80.

Hook-on board 2 500

Traditional forming/bending operation

Due to the number of working stations and the number of pre-setup machines, this is a very labour-intensive operation. The traditional forming/bending operation consists of nine employees. All nine of these employees are graded by the MEIBC on a level Rate G, which ensures that their minimum wage is R38.95 per hour.

Therefore, each eight-hour shift has a total cost of R2 804.40 and, according to the MEIBC, each employee works a total of 234 shifts during a 12-month period.

$$\begin{aligned} \text{Total cost} &= \text{Total cost per shift} \times \text{number of shifts} \\ &= \text{R2 804.40} \times 234 \\ &= \text{R656 229.60 per annum} \end{aligned}$$

Automated forming/bending process:

The automated forming/bending method that is suggested during this study is much less labour intensive and only makes use of two employees throughout the entire process. These two employees are graded by the MEIBC as a Rate D and a Rate G employee, and they earn R50.65 and R38.95 per hour, respectively.

The total normal working hours during each shift is eight hours and there is a total of 234 shifts during a 12-month period. The total cost per shift is R716.80 per hour when making use of the automated forming/bending process.

Therefore:

$$\begin{aligned} \text{Total cost per annum} &= \text{Total cost per shift} \times \text{number of shifts per annum} \\ &= \text{R 716.80} \times 234 \\ &= \text{R 167,731.20} \end{aligned}$$

Analysis of results

The traditional forming/bending operation is very labour-intensive and very expensive with a total cost of R656 229.60 per annum and R2 804.40 per shift. This is due to the labour that is required to operate each of the five machines during the manufacturing process. Each of these machines requires one operator and there is at least one general worker required between each of these operations to ensure the smooth flow from one operation to the other. The automated roll-forming process is one machine that is constantly performing the same actions as the traditional method, but without any human interference. This results in this process being much less labour intensive and it has a total cost per shift of R716.80 and R167 731.20 per annum. Overall, this results in a total manufacturing cost saving of R2 087.60 per shift and R488 498.40 per annum.

4 CHAPTER 4: RECOMMENDATIONS AND CONCLUSION

4.1 INTRODUCTION

The research thus far corroborates the benefits and value that may be gained by implementing semi-automated and automated manufacturing processes. The benefit manifests itself in increasing the profit margins as well as the throughput throughout the factory.

The research shows, through both time and motion studies as well as profit and loss calculations, that it is beneficial for a scaffold manufacturer to implement and introduce these semi-automated and automated production processes into their manufacturing systems.

4.2 THE RESEARCH PROBLEM REVISITED

The problem that has been researched within the ambit of this study reads as follows: Making use of semi-automated manufacturing processes the scaffolding industry should aim to achieve a superior quality product delivered to the clients in the shortest time possible.

The research proposes that it is indeed beneficial for scaffold manufacturers to implement semi-automated and automated manufacturing processes into the current manufacturing processes. During this study, the research considered various time and motion studies conducted at various times and, making use of the data gathered, we have arrived at the conclusion.

4.3 THE RESEARCH QUESTION REVISITED

The research question, forming the crux of this research study, reads as follows: What will the feasibility be for scaffold manufacturers to use semi-automated and automated systems within their manufacturing processes?

By making use of the time and motion studies and expressing my opinions in the profit and loss format, it is beneficial for scaffold manufacturers to implement semi-automated and automated manufacturing processes.

4.4 KEY RESEARCH OBJECTIVES REVISTED

The identified primary research objectives of this research study are listed below:

- **Primary objective:** The primary objective of this study is to determine whether it is feasible to implement semi-automated and automated manufacturing processes within the scaffold manufacturing industry. Through the results obtained in this study, it is clear that it is feasible for scaffold manufacturers to implement semi-automated and automated manufacturing methods. Not only are the semi-automated and automated processes more cost effective than the current traditional methods of manufacturing, but it is also increasing the throughput of the factory tremendously. The current concern in South Africa is the number of skilled workers in the welding and manufacturing industry that is increasingly decreasing, and, through this process, one could use the current skilled workers who are employed by the company in other segments of the business.
- **Secondary research objectives:** The secondary research objectives are:
 - i. Has the cycle time and the factory throughput improved? Through the time and motion studies it is clear that the factory throughput has improved tremendously and that there is a clear benefit for the scaffold manufacturers in the implementation of the semi-automated and automated manufacturing processes. Through the increase of the factory throughput as proved throughout this study, scaffold manufacturers in South Africa can increase their output without increasing their labour. The semi-automated and automated machines will reduce the floor space needed and increase the output tremendously.
 - ii. What is the most cost-effective method within the production processes? The data that was gathered during the course of this

study makes it clear that the most cost-effective methods in the production processes are the less labour-intensive processes. Semi-automated and automated production processes are using less labour and they are also increasing the factory throughput simultaneously.

4.5 RELIABILITY AND VALIDITY OF THE RESEARCH

Blaxter, Hughes and Tight (2006:221) provide an overview of the expectations of a research project relating to its significance, generalisability, reliability and validity. The following is adapted from the author's overview, with additional context provided to this research.

4.5.1 Significance of this research

Significance refers to the likelihood that a result derived from a sample could have been found by chance. The more significant a result, the more likely it will represent something genuine. In general terms, significance has to do with the importance of a particular finding (Blaxter, Hughes & Tight, 2006:221). During this study, the researcher contends that the significance of this study lies within the time and motion studies conducted; and that with minor adjustments, the methodology can be used in any organisation and is therefore not limited to the nuclear industry.

4.5.2 Generalisability

Generalisability relates to whether your findings are likely to have broader applicability beyond the focus of your study (Blaxter, Hughes & Tight, 2006:221). This study is biased towards manufacturing processes, but can be generalised for use in any other process. This may be done by modifying the time and motion studies that were used in this study.

4.5.3 Reliability

The concept of reliability has to do with how well you have conducted your research project. Have you carried it out in such a way that, if other researchers were to consider the same questions in the same setting, they would reach the same results? If so, your work can be judged as reliable (Blaxter, Hughes & Tight, 2006:221). The researcher contends that due to the standardisation in the time and motion studies taken, the research outputs may be repeated within the same context and environment, while being mindful of the identified uncertainties.

4.5.4 Validity

Validity has to do with whether your methods, techniques and approaches actually relate to the issues you have been exploring (Blaxter, Hughes & Tight, 2006:221). The research methodology used in this study in the opinion of the researcher contributes to and builds up the various elements to achieve the research objective.

4.6 FINDINGS AND CONCLUSIONS

The research showed that, by introducing semi-automated and automated manufacturing machines into the scaffold manufacturing industry, it can increase the profit margins of the company as well as the throughput of each of these operations. The research objectives that were answered were:

- Have the cycle times and the factory throughput improved?

Ledgers 2 500

The cycle times in the traditional manufacturing methods of the ledgers 2 500 have increased by 132 units per day. This is an increase of 41.772% per day without changing anything in the manufacturing process. This can lead to an increase in the company sales of 41.772% of a ledger 2 500 or a reduced lead time to manufacture this product.

Hook-on boards 2500:

The cycle times in the traditional manufacturing methods of the hook-on boards 2 500 have increased by 800 profiles per day. This is an increase of 108% on the current production, merely through the implementation of the automated roll-forming processes. This increase in the number of profiles will lead to an increase in the sales of the scaffold manufacturer and it will reduce the current lead time needed to manufacturer one hook-on board 2 500 tremendously.

- What is the most cost-effective method within the production process?

Ledgers 2 500:

Through the increase in the factory throughput of 41.772% per day and the decrease in the labour cost, this study can clearly show that the implementation of semi-automated ledger welding machines is beneficial for scaffold manufacturers all over South Africa. This machine will introduce a total labour saving of R94 816.40 per annum and an increase in the factory throughput of R2 441 696.40 per annum. This is a total benefit of R2 536 512.80 per annum that can be enjoyed by scaffold manufacturers for each semi-automated machine that is introduced into the manufacturing processes.

Hook-on board 2 500:

Through the increase in the factory throughput of 108% per day and the decrease in the labour cost, this study can clearly show that the implementation of automated roll-forming machines is beneficial for scaffold manufacturers all over South Africa. This machine will introduce a labour saving of R488 498.40 per annum and a decrease in the lead time for customers of 108%. This will result in the scaffold manufacturer being able

to deliver the material quicker and thereby increasing the factory throughput and profit margins.

4.7 AREAS FOR FUTURE STUDIES

Areas for future studies that emerged from this study are as follows:

- The findings of this study are entirely based on a study that was concluded at the manufacturing premises of one scaffold manufacturer based in Gauteng. This study should be carried out nationwide and the involvement of all scaffold manufacturers in South Africa can be beneficial. For future research, researchers can replicate this study for other automation processes within the scaffold industry throughout South Africa.
- More research is needed to determine the physical running cost of the machine and the cost that is related to the repairs and maintenance of the machine.
- More research is needed on the quality of the products produced and the consistency thereof through the automated processes. Future research can be done to ensure that the quality of the products as well as the consistency of the quality improve and/or stay the same whether automated, semi-automated or traditional methods are followed.

4.8 CONCLUSION

The scaffold industry throughout the world continues to grow year on year and with the always increasing health and safety standards as well as the Mining Act, scaffolding will continue to grow through the indefinite future as per recent studies and the literature review. Providing a safe access point, building/supporting a slab and/or bridge etc. will remain the responsibilities of scaffolding for the future. Through this investigation at one scaffold manufacturing plant in Gauteng, South Africa, it provided the researcher with clear insights into and conclusions for the questions raised.

Firstly, it was clear to the researcher that the market for scaffolding is growing throughout South Africa at a tremendous speed and that the skilled labour forces are not sufficient. Labourers who are skilled in the art of welding and machining are becoming scarcer by the day. Consequently, it was clear that the implementation of semi-automated and automated procedures is the way for the future. Through the implementation of semi-automated and automated machines in certain aspects of the manufacturing processes within the scaffold industry, it will free up certain key personnel who are skilled in the art of welding and machining. These personnel can then be utilised to grow the business in other areas with the current skilled labour that is available at the company's disposal. Quality standards in the scaffold environment are very important and therefore skilled labour plays an indefinite part in the manufacturing process of scaffolding and scaffold-related materials.

Secondly, the demand for scaffolding, as stated above, is increasing year on year and through the semi-automation and automation of scaffold manufacturing methods the factory throughput can be increased without relying on labour, which is scarce. The labour savings that resulted from the implementation of the semi-automated and automated processes can be reassigned to other processes within the scaffold manufacturing processes that cannot be automated. All construction projects are driven towards a completion date and therefore it is extremely important for construction companies to receive their scaffolding, which they have ordered, on time. Therefore, the scaffold manufacturing industry is extremely lead-time driven and their products need to reach their customers on time, otherwise the construction project is drawn to a halt. To deal with the demand that is increasing within the industry, the current scaffold manufacturers must either increase the plants size and capacity or it must invest in semi-automated and automated manufacturing processes. In order to increase their plant size, they must acquire a new property, new traditional welding machines, press brakes, guillotines and bending brakes, which is a large investment on its own. Through the implementation of the semi-automated and automated manufacturing processes, it will automatically free up the current machines that are in use. This will, in turn, put the company in the position to utilise the current machines that are in operation now in other operations in the company as needed. The company will also require a smaller space for the

manufacturing process due to the increase in the factory throughput and therefore the company does not need to invest in a larger plant. Through the implementation of the semi-automated and automated machines, the scaffold manufacturers will decrease their lead times through an increase in the factory throughput. This will help them to be able to deliver a quality product to their customers in a shorter time and thereby helping them to finish their projects on time.

Thirdly, the cost saving through the implementation of the semi-automated and automated processes is tremendous and this will increase the profit margins of the scaffold manufacturers tremendously. This, in turn, can reduce the cost of scaffold items and ensure that all contractors, builders and/or construction companies can afford to use scaffolding that is safer and more reliable than ladders and building trestles. By reducing the cost of the scaffold for your customers, it will, in turn, increase the production and the profitability of the manufacturers through fixed costs being utilised by a larger factory output. As per my research question, it is safe to say that the semi-automated and automated processes are indeed the most cost-effective way to follow in the production processes of scaffold manufacturers and that the research question has been answered in full.

The cycle times taken and the increase of the factory output by making use of the semi-automated and automated systems within the production processes prove that semi-automated and automated processes will indeed improve the factory throughput of scaffold manufacturers. This will be of tremendous value for scaffold manufacturers, because they can utilise the resources of the factory in a more effective manner.

From the above theory and empirical study, it is safe to say that it is indeed feasible for scaffold manufacturers to make use of semi-automated systems within their manufacturing processes.

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Appendix A

Cycle time studies for hook-on boards 2 500

Task	Activity	Time
Task 1: Hook-on boards – Traditional method		
	Guillotining	
	1 st Bend	
	2 nd Bend	
	3 rd Bend	
	Punch	
	Subtotal 2.5m product	
	Product length	
	Meters per minute	
	Thus: Total time for 2.5m HOB	
	Product length	
	Meters per minute	
Task 1: Automated		
	Roll forming of hook-on board profiles – Standard as per machine specifications	

Cycle time studies for ledger 2 500

Task	Activity	Time
Task 1: Tacking – Traditional method		
	Fetch part and place in welding jig	
	Tack the part together	
	Remove part from jig and place in WIP bin	
	Sub-total	
Task 2: Welding – Traditional method		
	Fetch part from WIP bin	
	Weld part in full	
	Place part in finished goods bin	
	Sub Total	
	Overall cycle time – Traditional Method	
Task 1: Automated		
	Fetch part from WIP bin	
	Weld part in full	
	Place part in finished goods bin	
	Overall cycle time – Automated method	

Appendix B

To whom it may concern

Dear Mr / Ms

Cecile van Zyl
Language editing and translation
Cell: 072 389 3450 Email: Cecile.vanZyl@nwu.ac.za

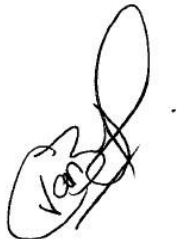
6 November 2017

Re: Language editing of dissertation: (A feasibility study of automation in manufacturing processes among scaffold manufacturers)

I hereby declare that I language edited the above-mentioned dissertation by JC Engelbrecht (student number: 21144893).

Please feel free to contact me should you have any enquiries.

Kind regards

A handwritten signature in black ink, appearing to read 'Cecile van Zyl', with a large loop at the end of the last name.

Cecile van Zyl
Language practitioner
BA (PU for CHE); BA honours (NWU); MA (NWU)
SATI number: 1002391

Appendix C



NORTH-WEST UNIVERSITY
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10 March 2017

ETHICAL CLEARANCE

This letter serves to confirm that the research project of **ENGELBRECHT, JC** has undergone ethical review. The proposal was presented at a Faculty Research Meeting and accepted. The Faculty Research Meeting assigned the project number **EMSPBS17/03/06-01/02**. This acceptance deems the proposed research as being of minimal risk, granted that all requirements of anonymity, confidentiality and informed consent are met. This letter should form part of your dissertation manuscript submitted for examination purposes.

Yours sincerely

Prof CJ Botha
Manager: Research - NWU Potchefstroom Business School

Original details: Wilma Pretorius(12090298) C:\Documents and Settings\Administrator\My Documents\Briewe MBA\2017\