The impact of implementing selected lean principles in a South African gold processing plant

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It all starts here ™

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ABSTRACT

This study explored the theoretical aspects of Lean Manufacturing principles and identified the practical implementations for a gold processing plant. The success rate of Lean implementations is currently as low as 5% and can be attributed to the failure of management to address the effect of implemented changes on the employees. With this risk in mind, the study included a measurement of the worker perception towards change and organisational climate. The impact of Lean Manufacturing principles was thus quantified by means of practical projects, including an empirical study of how open employees are towards change implementation.

The plant process was described and the flow of value was mapped in a Value Stream Map (VSM). The applied principles resulted in three proposed improvement projects with the potential of reducing operating cost, generating additional revenue and eliminating waste. The proposals included reducing lead times through the plant for the two feed sources, namely reef and waste material by 4% and 51% respectively; improved recovery of fine carbon as a by-product of the treatment circuit; and lastly, reducing the lead time for conducted elusions by improving the “flow” of solution throughout the batch process.

The quantified financial benefits of the improvements were an estimated additional revenue of R180,000 per month and a further cost saving of R4,000 per month. This study explained that multiple spin-off benefits are realized when improvements are based on Lean Manufacturing principles. Some additional benefits were listed but not quantified in this study. It is important to notice that these specific identified improvements did not require additional capital expenditure, nor long lead times to be implemented. Requirements included an open mind towards change management, time and effort.

A survey was conducted to measure the employees’ readiness for change management and the stability of the organisational climate. In the South African mining context, there are external factors impacting on operations of which labor, unions and worker productivity are among the foremost aspects of current concern. This served as motivation for the survey to test employee readiness for Lean Manufacturing changes to be implemented.

The statistical internal consistency of the questionnaire, as expressed by the Cronbach alpha coefficients, was acceptable at 0.773 and 0.759 for the change management and organisational climate factors respectively. The p-values and effect sizes were determined

within the T-test and ANOVA tests. The group consisting of different years' experience yielded the most statistical differences in the way that the organisational climate section was completed. The indication was that highly experienced employees answered the questionnaire significantly different than the other groups. The average scoring for the section was above the average and therefore was not considered to be a significant risk to implementation.

The group is considered ready for change implementation and the plant should proceed to implement the identified Lean projects. The success and sustainability of the projects can encourage additional improvements. The recommendation is to revisit the future VSM after completion of the projects to identify the next level of improvements for implementation.

Key concepts: Lean Manufacturing**,** value chain**,** Value Stream Map**,** organisational climate, change**,** waste elimination**,** projects, implementation

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Chapter 1 **Contextualisation of the study**

1.1 Introduction

Lean is a term that has been used synonymous with an array of business improvement initiatives over the years, and follows the customer's point of view of creating value, eliminating waste and continual improvement initiatives. It can be applied to supply chains, production/manufacturing and service divisions, as well as customer care and support. According to Eaton (2013) it provides those who are prepared to invest time into some structured common sense, and the ability to move from the "as is" to where they "want to be". It is therefore aimed at the practical sequences and tools that assist in turning your strategy into a reality, and is based on introducing change into the workplace.

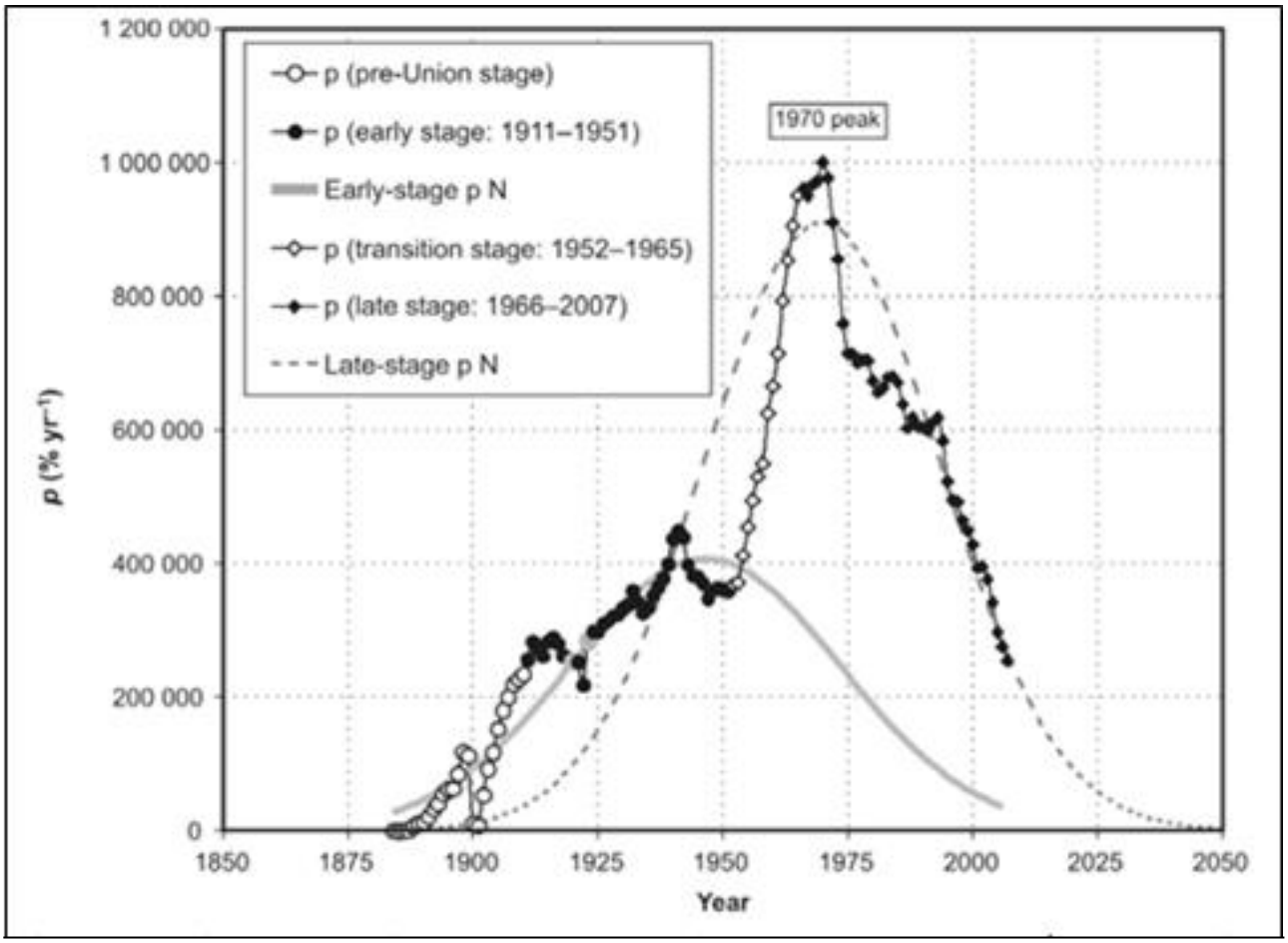
The gold mining industry is dependent on the gold price, which changes according to supply and demand. In 2013 the gold price recorded one of the fastest declines, from $1600 per ounce to below $1200 per ounce within 12 months. This resulted after the announcement from the American Federal Reserve concerning the cut backs on the economic stimulus packages for the U.S. This signal was interpreted as the recovery of the U.S economy and the market responded in favour of the dollar. The need for a gold "safe haven" against inflation and interest rates declined, setting off a fall in gold price (Recknagel, 2013). Companies had to improve efficiencies, productivity and costs in order to survive this low price period.

1.2 Problem statement

Gold production has been declining year on year in South Africa, due to depleted ore bodies and the increased depth of the remaining reserves. These days the South African gold mining companies rather explore overseas for future expansion opportunities. These new ore bodies are more accessible, compared to the remaining ultra-deep deposits in South Africa, and therefore are more economically feasible. According to D'Oliveira (2014), the South African gold mining sector will struggle to compete against other gold producing nations, such as Australia, Canada and China, unless the productivity issues can be resolved. The gold price fluctuations contribute to the complexity of the industry and compel South African operations to opt for different business strategies that can change or at least slow down its ultimate fate.

Eliminating waste and expanding value can attract new investments and extend the life of operations. Gold mining in South Africa is seen as a “sunset industry”, which had its best years in the 70s, as indicated in **Table 1.1.**

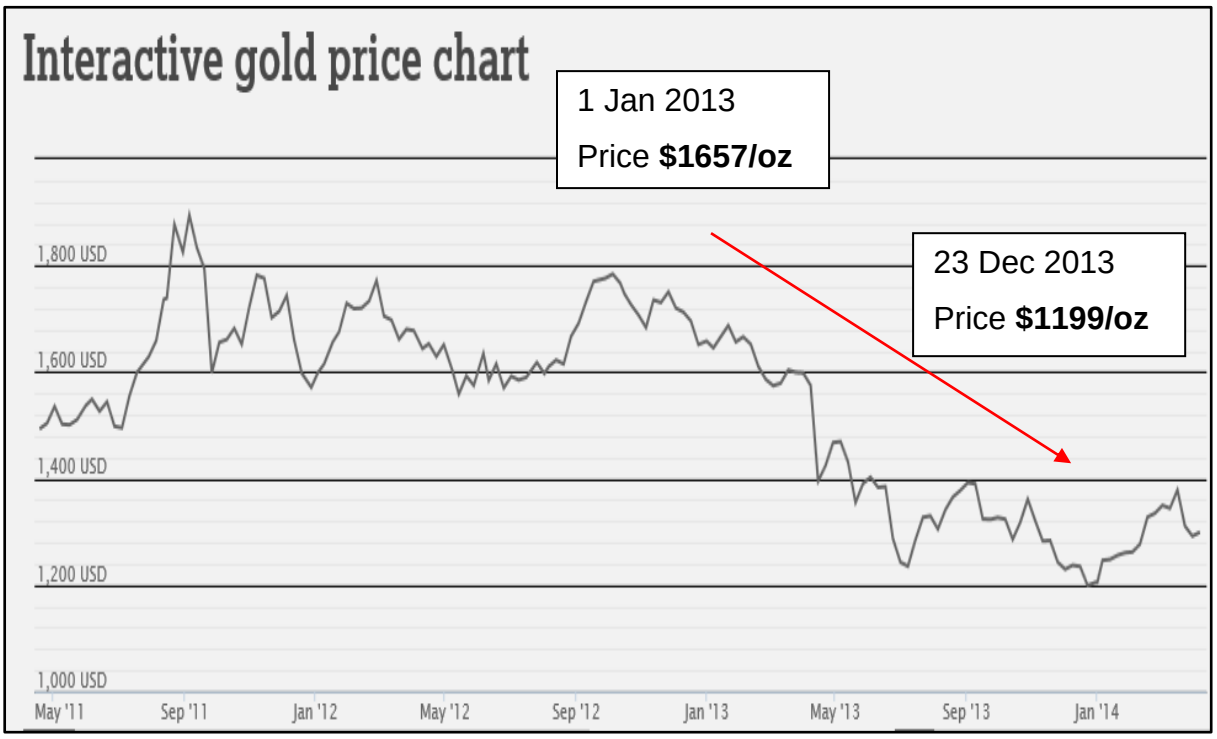
Table 1.1 South African gold production



Source: http://www.bullion.org.za

In the current economic climate it is not feasible for South African processing plants to invest in technological changes that require large amounts of capital. The need is therefore to improve productivity by means of implementing different business strategies and applying different approaches to the same problems. The question is whether Lean Manufacturing principles can lead to improvement initiatives on the plant, which in turn could result in financial savings and improved productivity. This is required for the survival of the industry after the last sudden drop in the gold price during 2013. In **Table 1.2** the 27% reduction in the gold price during 2013 is illustrated.

Table 1.2 The gold price history for the last 3 years



Source: http://www.gold.org/investment/interactive-gold-price-chart

There is a need for a change in thought in order to spark a continuous improvement regime to withstand the difficult economic climate, and provide a leading edge to compete with peers in the same market segment.

Prior to embarking on implementing the changes, it would be beneficial to take cognisance of the fact that the employees in the sector are mostly unskilled labour. The work force is highly unionised, and due to low trust levels, the introduction of technology or projects can be perceived as a threat to job security, and thus may be resisted. According to McMahon (2013), the latest studies indicate that Lean Manufacturing implementation failure rates are between 50% and 95%. One of the reasons may be that the employees were neither engaged nor consulted on the changes that were associated with the Lean Manufacturing implementation. Therefore this dissertation includes an empirical study to gauge the readiness of the employees towards implementing changes in the workplace. The willingness of the employees to participate and drive continual plant improvements, are perceived as one of the major risks for implementation.

1.3 Objectives of the study

1.3.1 Primary objective

The primary objective is to:

- Utilise the theoretical Lean Manufacturing principles to identify opportunities in the processing plant that can improve productivity, save costs or generate additional revenue. Demonstrate the potential of Lean Manufacturing principles by means of quantified data.
- Investigate the process flow by means of the current Value Stream Map (VSM) that provides a graphical representation of how the raw material flows through the respective plant sections. By utilising the experience and knowledge of the employees, it analyses the plant sections for potential improvement according to the basic Lean Manufacturing principles.
- Areas within the process that are currently batch processes, will be evaluated for their potential to be converted or improved towards continuous processes, as well as apply the material “pull” concept to reduce plant inventories and thereby reduce the lead time.
- Illustrate that successful plant-based projects can be implemented without the need for external resources or large capital investments. It is possible to utilise existing infrastructure and equipment to increase productivity and efficiency.
- Apply actual quantities and measurements to calculate financial benefits where possible. Once the improvement opportunities are identified, an effort must be made to identify and quantify benefits, as well as create confidence that the solutions are sustainable.

1.3.2 Secondary objectives

The secondary objectives that support the primary objective are as follows:

- Utilise a measuring questionnaire to obtain employee perceptions of the current organisational climate and management of change, as a measure of employee readiness towards change. Implementation of the principals depends on support from employees, since all ideas are generated internally.
- Identify whether different groups within the sample harbour different perceptions (age, ethnicity and job level).

- Recommendations concerning the required effort on the equally important “respect for people” aspect of Lean Manufacturing. It is essential to take employees along on the journey, therefore employee perceptions are measured as a secondary objective that supports the implementation of Lean Manufacturing principles.

1.4 Scope of the study

1.4.1 Field of the study

The fields of the study include operations management, with the primary goal of achieving increases in productivity or savings on operating costs. Organisational behaviour is a secondary field, since the chances of successful implementation of Lean Manufacturing is limited if employees are not ready for change implementation. The field of Lean Manufacturing and Lean production has been well researched, but successful applications within the mining industry are limited. For the purpose of this dissertation, the results are applicable only to specific processing plants and their internal services departments.

1.4.2 Industry, organisation, place and sector

The application of Lean principles will be conducted on a processing plant of a global gold mining company. The South African economy has been built on the gold mining industry as is explained further on in the literature study. The industry is known for the use of migrant labour and its active unionism (Hartford, 2012). The respective plants where the test work and experimental data will be obtained from, is situated in the Gauteng Province of South Africa.

1.5 Research methodology

1.5.1 Literature study

The literature resources for this study are in the form of journals, articles, books, media, and databases with articles from the Internet.

Databases:

- ScienceDirect: Scientific database offering journals and books;
- Emerald: Global publisher that links research and practice;
- EbscoHost: Published journal articles;
- Springer: Peer reviewed journals;
- National ETD portal: South African thesis and dissertations;

- Proquest Dissertations: International thesis and dissertations;
- Sabinet;
- Googlescholar;
- Text books;
- The Internet;
- Lecturers;
- Authorised company documents; and
- Literature on current applied systems.

1.6 Empirical study

1. Qualitative study: Implementation projects

The value chain will be illustrated with a “current state” value stream map (VSM), from which the recommendations for projects, based on applicable Lean principles will be developed. The team of metallurgists and engineering employees will be gathered in order to work through the VSM map. The main principles of Lean Manufacturing will be explained to the participants in order to collaborate on where the system could be applied within the sections.

Physical visits to the sections will be required to visualise the actual flow of material. The brain storming session should provide some ideas which could then be screened for implementation.

The proposals should:

- Be completed within the current working cost structure;
- Be according to the Lean principles;
- Be quick to implement in order to realise benefits in terms of either cost, additional revenue or productivity; and
- Be sustainable.

The desired “future state” VSM will be drafted to illustrate the benefits in terms of production lead time and additional processing steps that add value or remove wasteful steps. This qualitative data for the proposals will be further developed into steps for implementation.

Measurements of gold bearing material and quantities will be physically taken to ensure accurate calculations.

2. Quantitative study: Statistical analyses of the perception survey

The data obtained from the perception survey will be used to measure if the employees are in support of the continuous changes that are associated with implementing Lean Manufacturing. The questionnaire will be circulated to a selected sample of employees and statistical analyses performed. The questionnaire's reliability will be subjected to Cronbach's alpha coefficients to validate internal consistency. From ANOVA and T-test statistics, the effect size and statistical validity will provide more background regarding the different perceptions of the respective groups that participated. The objective is to gain an understanding of whether employees would support the continual changes that are associated with Lean Manufacturing. The statistical results could indicate to management whether employees are ready for the changes associated with Lean, or whether there are negative perceptions which could pose a risk. According to Liker (2004), respect for people is very important in the implementation of continuous improvements.

1.6.1 Construction of questionnaire

1. Quantitative study

The questionnaire will be divided into two sections, starting with detailed participant information, such as gender, age, ethnicity, experience and position. The second part will be exploring the workers' perceptions on readiness for change, and measure if the current organisational climate is conducive for continual changes associated with Lean Manufacturing. The format will be on a five point Likert scale which ranges from "Strongly Disagree" to "Strongly Agree".

An example of the structure:

Table 1.3 Example of the questions

I am excited when we change old practices	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

The objectives of the questionnaire are:

- To form a base opinion on workers' perceptions regarding change management, systems and organisational climate;
- To evaluate the differences in the answers from different participating groups; and
- To gauge the willingness of employees to accept, participate or lead implementations.

Considerations may be reserved when the value stream map for the plant is analysed for improvements. It will thus be apparent from the organisational climate should the identified opportunities be well received, according to measured worker perceptions.

1.6.2 Study population and sample

1. Quantitative study

The population consists of employees working on gold processing plants within a certain organisation in South Africa. Operational management aspects are similar across various processing and extraction plants, but application to different commodity processing plants will need to be verified with further research. The sample for this dissertation will include 10% of the total plant compliment for all 4 gold plants, situated in the North West, Gauteng and Free State Provinces. The total sample size is estimated at a minimum of 100-200 participants, from the total distribution. The total compliment across the gold plants is 2000 people; therefore a 5-10% representative sample will be used as the source for the questionnaire portion.

1.6.3 Data collection – Qualitative and quantitative studies

1. Qualitative study

Certain projects that are recommended will entail the sampling of gold bearing material in order to determine whether a viable project could be motivated. The samples will be processed at the central laboratory as well as the data obtained from the chief chemist. Sampling standards and statistical measures will be utilised to ensure that the samples are representative of the material involved, in order to make well founded and reasonable recommendations. Thus, actual data will be used for the proposed improvements to the future VSM.

2. Quantitative study

Days will be scheduled to visit the plant and to attend their staff safety meetings in order to utilise the time slot for collecting the survey data. An employee list will be used to ensure that the questionnaire is distributed evenly to a vertical cross cut section of the department, in order to ensure that the data represented the total population.

1.6.4 Statistical analyses

1. Quantitative study

Basic descriptive statistics, such as standard deviation, mean and percentiles indicate the dispersion, and the array of answers that will be obtained from the questionnaires.

The T-test and ANOVA analysis will be performed by the Statistical Department of the North-West University, Potchefstroom Campus, utilising Statsoft statistical software (Statsoft, Inc. 2010). The T-tests will evaluate if the difference between 2 means are statistically significant while the ANOVA will been applied where more than 2 groups need to be analysed within the sample. The relevant p-numbers and effect sizes will be used to quantify the differences and to assess whether these are statistically significant.

The information obtained from the questionnaires will be used for guidance in the selection of value chain improvement projects, as well as to direct the implementation of Lean tools.

1.6.5 Limitations of the study- Qualitative and quantitative studies

The data obtained for the proposed projects will be based on actual data. Limitations could be the result of the representativeness of potential gold bearing samples. Statistical tools will be applied to establish the level of confidence in the data. The operational data used in this project will be obtained from information sources available on the plant itself, and may be verified for accuracy and precision.

Application of the Lean interventions may be recommended for selected groups, but only if it is perceived that the benefit could be maximised within the structure. The observational data could therefore be limited to selected groups within a single gold plant and within certain groups only.

The survey questionnaire will be based on worker perceptions. The data will be confined to a single company in South Africa, within the gold industry. The data is aimed at

representativeness for the specific company within the gold industry and not necessarily directly applicable to other commodities or companies.

1.7 Layout of the study

- Chapter 1 Introduction to the content and an explanation of the topic. This section includes a problem statement, data types, a scope of the study and study limitations.

- Chapter 2 The literature review with regard to Lean Production and Lean Manufacturing, as well as its applicability to the mining, resources and mineral processing industries is explained.

- Chapter 3 The research method is explained in order to achieve the desired objectives. This section will cover the measurement instruments used, together with the data analysing techniques.

- Chapter 4 The results will be discussed and the potential impact on the business unit included. The conclusion of the research and recommendations for implementation will be incorporated in this chapter. In summary, the value proposition to the business unit is revealed and direction is provided for future studies.

Chapter 2 **Literature study**

2.1 Introduction

The purpose of the literature study is to provide knowledge of the principles regarding Lean Manufacturing as a business improvement initiative. Its origination demonstrates the diverse inputs which resulted in a system that is applicable to any industry, across all disciplines and within various business units. The implementation methodology and sequence are explained and it is perceived to promote and support the current improvement initiatives within the gold plant, in such a way that it becomes essential to normal operations. Lean Manufacturing depends on behavioural aspects; the cultural acceptance of change is analysed in order to understand the potential pitfalls and challenges involved with change management implementation.

2.2 Gold mining in South Africa

Prospecting for gold in South Africa peaked in 1886, with the discovery of the first commercially viable reef by George Harrison (Anhaeusser, Feather, Liebenberg, Smits & Snegg, 1987:1). This is a continuance of a series of gold rushes during the 1800s that started in California in 1849, moved to Australia in 1851, New Zealand during the 1860s, again in Australia during the 1870s, to South Africa in the 1880s and back to Western Australia in 1893 (Richardson & van Helten, 1984). The commercial gold market is currently 128 years active in South Africa, since the main reef that lead to the founding of Johannesburg in 1886, was discovered (Shorten, 1970).

Gold, as a precious metal, is considered extremely rare and does not oxidise or corrode over time in the natural atmosphere, making it virtually indestructible. When gold is produced, it is sold to a central refinery which upgrades the purity from 90% to 99.99% (Marsden & House, 2006:459). Metal shares are regularly bought by fund managers as a hedge against depreciating currencies, especially during periods of economic recession and depression. The gold price moves according to the supply and demand market principles on an international scale in US dollar currency. A single company seldom has a significant influence on the overall market price. The resources-and-processing industry has no direct internal competition in terms of selling the product. With this lack of direct competition, industry improvements to increase profitability, are dependent on management functions with regard to finances and production. The price of the product is at the mercy of the market price and the exchange rate.

2.3 History of Lean

2.3.1 What is Lean?

When the history of Lean is researched, it becomes evident that the amplitude of information or “jargon” available, may quickly lead to the premise of an ideology rather than an applicable and implementable system. According to Stone (2012), the importance of a shared language, must first be initiated to describe the ideas and concepts of Lean. Bill Carreira (2005) explains it as a way of thinking and an overall philosophy with regard to running a business. According to Eaton (2013), Lean is a structured common sense, based on customer requirements and the adaption of the business accordingly, within time and cost constraints. The work by Womack and Jones (2003:15) describes Lean as the way to do more and more with less and less, while aiming to provide customers with what they want. The identification of waste, in order to eliminate it, is what lies at the core of Lean, according to Schniederjans, M.J., Schniederjans, D.G. and Schniederjans, A.M. (2010). Elements of Lean, such as continuous flow and standardisation, can be traced back as early as 1473, when the Venetian Arsenal used these techniques to produce an entire ship in under an hour (Eaton, 2013).

According to Eaton (2013), the timeline for elements of Lean with various contributors over the centuries and decades, can be followed as illustrated in **Table 2.1** below.

Table 2.1 History depicting elements of Lean Manufacturing

Date	Location	Industry	Description
1473	Venice	Armed Forces	**Venetian Arsenal -** utilised continuous flow with mass produced and standardised items to produce a ship in under an hour.
1776	France	Armed Forces	**Lieutenant General Jean-Baptiste de Gribeauval** - Reduced diversity of artillery by

			standardising the range and using interchangeable parts.
1799	USA	Supplier to Armed Forces	**Eli Whitney** - Mass produced muskets to the US army by using interchangeable parts and a standardised process.
1894-1912	USA	Theory Literature	**Frederick W Taylor** - Wrote on improving efficiency in 1911; How to eliminate inefficient practices.
1905-1921	USA	Theory Literature	**Frank and Lillian Gilbreth –** Wrote on improving efficiency through a time and motion study, published in 1921.
1910	USA	Motorcar	**Henry Ford** – Created the first moving assembly line in 1914, reducing production time by 75%.
1924-1939	USA	Electric	**Walter Shewart** – Father of quality control; develops the concept of statistical control of processes; although Six Sigma, it shares concepts of Lean.

1943	Japan	Motorcar	**Taiichi Ohno** – Created the Toyota Production System (TPS) after joining Toyota in 1947. Cell working, waste reduction, reduction of work-in-process, in-process inspections and respect for people principles.
1983	USA	Theory Literature	**Robert Hall** – Publisher of *Zero Inventories;* includes a description of TPS by an American author.
1988	USA	Theory Literature	**John Krafcik** – Is accredited with the first use of the word Lean in association with the Toyota Production System. His paper was: "Triumph of the Lean Production System".
1990-1996	USA	Theory Literature	**Jim Womack, Daniel Roos and Dan Jones** – They wrote "The Machine that Changed World" in 1990. Womack and Jones went on to write "Lean Thinking" in 1996. This

			introduced the term into the public domain where it is still used.

Source: Eaton (2013: 6)

In the operational environment are numerous terms that have been used over the years for the different approaches to continuous improvement and quality initiatives. Herewith follows a few other definitions of some business improvement terms that changed the way in which value is transferred to the customer and are frequently mentioned together with, or as part of Lean:

- TPM Total Productive Maintenance

  A production development by Saiichi Nakajima from Japan, in 1988 (cited by Singh, Gohil, Shah & Desai. 2013), which uses preventative maintenance at high quality, resulting in boosted morale of employees. The overall equipment effectiveness is a measurement used in manufacturing to evaluate the TPM system. It is normally used together with TQM in the manufacturing industries (cited by Singh *et al*., 2013).
- TQM Total Quality Management

  Individuals instrumental in this quality movement, included Walter Shewart, W. Edwards Deming, Joseph M. Juran and Phillip B. Crosby. It was Shewart who started first during 1920's, at the Bell laboratories in the USA, to use SPC in order to measure variability (cited by Zairi, 2013). Both TQM and TPM are required, according to Imai (2012:7), in order to conduct successful continuous improvement programs in the workplace or "Gemba Kaizen" in Japanese Lean terms.
- Six Sigma

  It is a quality driven management system, for which the term originated in the 1970's when a Japanese company took over Motorola in the USA. The success of quality improvements at Motorola has resulted in Six Sigma becoming renowned in the business world (Pyzdek & Keller, 2010:4). Problem solving tools and statistical process control, forms part of the methodology of DMAIC, which is the abbreviation for Define, Measure, Analyse, Improve and Control (Eaton, 2013:50).
- PDCA

  This work was originally presented by Dr W Edwards Deming in his lectures, while working in Japan during the 1950's. The circle is Deming's version of the Shewart

cycle, originally done by Walter Shewart in 1939. The Japanese used this in their development of TQM and quality circles. The plan-do-check-act is well known as the circle for continuous improvement (Moen & Norman, 2009).

- Theory of Constraints
  Introduced by Goldratt and Cox (1993), it uses value streams to establish the reasons for lack of flow or "constraints" (cited by Melton, 2005).

Lean cannot be assigned to a specific person, company or even country. Though the Toyota Company was the earliest implementer of Lean principles, which were part of the Toyota Production System (TPS), it remains a system with contributions from many people over many years (Schniederjans *et al.*, 2010). With such a long history of concepts, it is evident that Lean is not just another management "fad" with no effect on business. There are success stories of global businesses which were in a downward spiral towards business failure, but turned around by implementing Lean principles. In the book "Lean Thinking" by Womack and Jones (2013), referenced companies include Lantech, Wiremold, Pratt & Whitney and Porsche that turned losses around after implementing Lean principles.

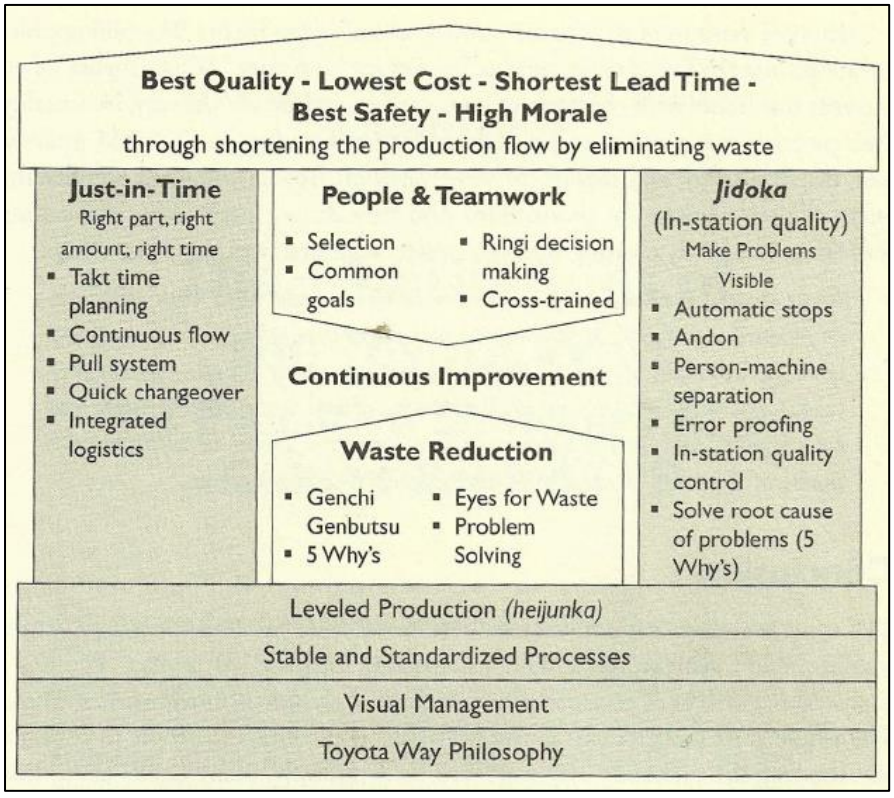
2.3.2 From the Far East – Toyota Production System (TPS)

The Toyota Company became well known in the 1980's for producing reliable cars consistently and developing new models at a fast pace. All of this was done economically, considering the high labour costs in Japan at the time (Liker, 2004). At the time of the literature by Liker (2004:4), the company was the most profitable of all motor manufacturing companies. This was all thanks to the system that Toyota embarked on from early on called the "Toyota Production System". The summarised objectives of TPS are "thorough elimination of waste and respect for humanity" (Liker, 2004).

The credit for creation of the TPS as it is known today, is given to Taiichi Ohno, who worked within the company and became Executive Vice President of Toyota, and Shigeo Shingo, a consultant to Toyota. Key roles were also played by Kiichiro Toyoda, former president of Toyota, and Saito Naichi (Emiliani, 2006). Both Toyoda and Ohno were influenced by American industrialist, Henry Ford, through his books "My Life and Work" and "Today and Tomorrow". Another contributing system was termed "Training Within Industry Service" (TWI), a system created by the US Government and came to Japan in the 1950's as part of the allied efforts to rebuild industrial infrastructure (Emiliani, 2006).

The post Second World War motor manufacturing industry in Japan was very different from its peers in the USA. The Japanese could not focus on large mass production and economies of scale, as was the case with the USA during that time, but instead had to make do with what they had and was required to produce a variety from single production lines. This called for great flexibility in order to fulfil customer needs (Liker, 2004). What makes the TPS such an evolutionary achievement is that Japan does not have its own resources, it is an island surrounded by sea and all resources need to be imported. The market is small in comparison to the USA which makes Toyota's success even more significant. One essential difference between Mass Production and TPS is that the elimination of time and effort, by running the labour and machines as hard as possible, is not necessarily ensuring that raw materials get effectively transformed into saleable products. The Mass Production model established material-flow by establishing the assembly conveyor system, which inspired Taiichi Ohno. In his book, Henry Ford alludes to continuous material flow, standardised processes and elimination of waste, but in reality the work-in-process inventories were high and the strategy lacked focus on customer needs (Liker, 2004). The core TPS model, illustrated in **Table 2.2** below, is essential to the foundation of Lean Manufacturing.

Table 2.2 TPS model



Source Liker (2004)

There is plenty literature available on the way that Toyota achieved its success, but the work by Dr Jeffrey K. Liker in 2004, delves into the underlying philosophy and culture of the Japanese manufacturer. His work is summarised in 14 foundational principles that enable the TPS system to function effectively. See in **Appendix 1**.

2.3.3 To the Great West

The first notable contributor from the West was Henry Ford, who established the mass production assembly line in 1914, as illustrated in the timeline in **Table 2.1**. The mass production principle is focussed on continuous flow and interchangeable parts in order to manufacture high volumes of product to fulfil demand (Liker, 2004). There was no variety and therefore the Ford production line was completely focussed on effective production and bringing the motor car within the reach of average citizens. He is also renowned for "creating" the middle class by paying higher wages to factory workers (Wicks, 2003). The TPS adopted the concepts of "work flow" and "standardised processes" from Henry Ford, but these formed only part of the Toyota system. The Lean Manufacturing system evolved further around the "customer value" and "waste elimination" perspectives (Womack & Jones, 2003:7).

It was as early as 1971 that Peter F. Drucker noted that the West has a lot to learn from the Japanese way of managing business. In his paper on Japanese management, he refers to the Japanese concepts that opposes Western thinking but yet is the key recipe for its business success (Drucker, 1972:3). It was only during the late 1970's that the USA seriously considered the TPS and Lean principles in order to improve business variables. The first company to apply it was Kawasaki in Lincoln, Nebraska, in 1975 (cited by Emiliani, 2006:170). The business press gave TPS and Lean more coverage during the early 1980's which resulted in numerous other implementations.

The establishment of Productivity Inc. in 1979 started the publishing and advocating of Japanese management principles within the USA. General Electric (GE) conducted visits to Japanese companies in 1980 and 1981 to conduct studies of their manufacturing practices. It was a general manager within GE, named Arthur Byrne, who later (in 1982) implemented TPS and Lean principles within the Wiremold Company which became an example used in the book "Lean Thinking" by Womack and Jones in 1996. The Toyota

Company became directly involved in the USA when a joint venture with General Motors resulted in the establishment of the New United Motor Manufacturing Inc. (NUMMI) during 1984. The USA Government noted the Japanese competition and funded a study in 1985 to establish the differences in manufacturing practices. This study was responsible for delivering the paper in which the term “Lean” was first associated with TPS (Emiliani, 2006:172). A Massachusetts Institute of Technology (MIT) graduate, John Krafick, who had been an engineer at NUMMI, wrote the article “Triumph of a Lean Production System”, which was published in 1988. The paper highlighted the waste associated with batch-and-queue systems. During this study the term “Lean” became the all-encapsulating term for TPS and its related developments (Eaton, 2013:5).

Lean transformations took place across the USA with the assistance of Japanese consultants from Shingijutsu Co. Ltd in Japan. There are numerous success stories captured in literature, but failed implementations were more common. The study by Emiliani (2006:178) concluded that the implementation of the second leg of Lean, namely “respect for people” did not get the attention it deserved. The focus remained business orientated with continuous improvement as the objective. What the USA failed to realise was that the second part enabled the function of the first part. Without implementing both parts of Lean, the chance for success was limited. Other reasons for failure include Lean system implementations for short term labour cuts and/or cost cuts or only implementing selective portions of the system (Emiliani, 2006:178).

2.4 Concepts explained

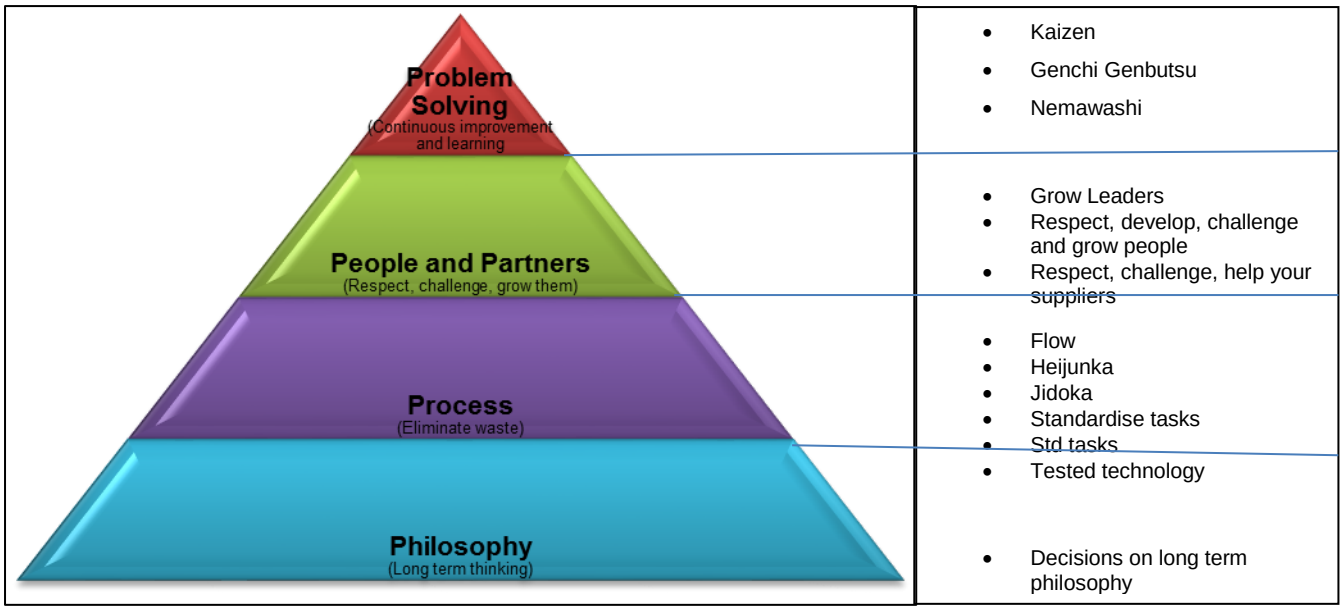
2.4.1 The comprehensive 4P model

The Lean system consists of an array of different parts that need to be implemented together in order to realise the full potential of the system. When starting out it is important to set the scope of the project and clear objectives. The “4P” model provided by Liker (2004:6) is a proper starting point for visualising the Lean Manufacturing process as a whole. The layout is illustrated below in **Figure 2.1**.

At the foundation of the triangular model is the philosophy for the long term which relates to more than a conventional management strategy. It sets the philosophy which the company should live by, a sense of purpose, and what it should stand for. It entails a lot more than financial planning. The Japanese philosophy is “employment for life” and

"decision by consensus", hence these are situated at the foundation of the model (Drucker, 1972:2).

Figure 2.1 The 4P model



Source: Liker (2004)

The process portion includes the implementation tools and is the most used part of Lean Manufacturing implementations. According to Liker, if these implementations are conducted in isolation from the rest of the model, it will eventually lead to failure, because the employees are not aware of the direction or the benefits of Lean Manufacturing (Liker, 2004:13).

The people and partner level is next, where employee engagement and mutual respect is fostered. The relationship with suppliers and other partners are considered just as important as between employees.

At the peak of the 4P model is problem solving through continuous improvement and learning. The pursuit for perfection never stops and there are various instruments that can be used.

2.4.2 The Value Stream Map (VSM)

The value stream is a list of activities that an organisation should undertake to deliver on a customer's request (Womack & Jones, 2003:38). The Value Stream Map (VSM) is a "flow" diagram consisting of actions or processes that are required to bring a product from its raw

materials into its final form (Rother & Shook, 1999). The steps can be value-creating or not, but all are included in the map, together with information flow. The map has its own legend that consists of icons and arrows that represent the Lean terms and tools and is widely available from literature, such as the work by Rother and Shook (1999), or within flow diagram software such as Visio by Microsoft. A list of the standard shapes and icons used is provided in **Appendix 4** and was obtained from an article by Braglia, Carmignani & Zammori, (2006). The map forms a bigger picture of the overall process and is analysed from the customer's point of view in order to realise the sources of waste and potential improvements.

The VSM can be used for more than just to reduce operational waste elements, its methodology is value-based and can transform leadership thinking, while contributing towards strategy and priority setting (Martin & Osterling, 2014:xvii). The advantage of a VSM is that the overall picture that extends across various departments and sections are displayed and therefore considered in proposed changes. The boundaries of the VSM are the starting point, and in this case starts where gold bearing material enters into the plant from the mine. The end point is at the smelt house inside the plant, where the gold bullion is produced and dispatched to a refinery.

According to Martin and Osterling (2014:19), the VSM is used for strategy, while ordinary "process maps" contain the details for tactical improvements. The VSM is mainly for the people overseeing improvement work, while process mapping is applicable to the actual people who conduct the improvement work. It is important that the team drafting the future VSM has sufficient authorisation in order to make the proposed changes. Precious time is wasted if there is a series of authorisation hoops and hurdles to cross prior to implementation. Making sure that the relevant managers are on board prior to the finalised future, VSM will enable swift progress (Martin & Osterling, 2014:45).

The VSM example in the literature by Rother and Shook (2009:23) implies that processes which "produce according to a schedule" is automatically labelled as a batch and push system. This is mainly due to the lack of customer demand for the product being manufactured. Customer demand in the gold industry has always been there. It represents an international "currency", and is collected as a hedge against economic down-turn, therefore the customer-driven demand creates a maximum "pull" factor within the operation. In the event that gold should be kept or stored for later sales, the process could

have been perceived as a “push” system that produces unwanted product, but this has not been the case within the industry up until now. As soon as gold is produced and delivered to the refinery, it gets sold.

2.4.3 Lean terminology

The amount of literature available on Lean is overwhelming and contributes towards the complexity of its implementation. Some of these single items can be a complete major project in itself and take years to complete. Toyota has spent decades implementing the TPS system and it is by no means completed. The Lean Manufacturing elements can consist of a complete system within itself. For example, the Kaizen element consists of quality, improvement and maintenance aspects which might be covered in other elements as well. This might cause confusion, as there is no single way to introduce Lean into a company. According to Bhamu and Sangwan (2014:877), Lean Manufacturing can be viewed from two perspectives, consisting of either a philosophical view, that is focussed on guiding principles and goals (Womack & Jones, 2003) or a practical outlook, consisting of tools, techniques and practices (Shah & Ward, 2003). Herewith follows short descriptions of some Lean Manufacturing implementation elements applicable to the gold plant, with principles and its intended objectives.

Principles

- Value

  Lean Thinking starts with value for the customer of which production plants act as the vehicle that delivers this value. If the value to the customer is not understood, the process cannot move any further (Melton, 2005). In the work by Bill Carreira (2005:2), he defines value in Lean Manufacturing with the following question managers have to ask themselves: “Does this activity directly contribute to my customer’s product’s becoming more complete, and is the customer paying for this activity to occur?” Value is defined from the customer’s point of view, thus it is required to put on the shoes of the customer and ask the questions from that perspective.
- Muda

  The Japanese word for “waste” is muda, and prevails at the core of Lean Manufacturing. All the actions within the manufacturing plant that does not add value to the customer, is considered as muda (Eaton, 2013:34). The 7 wastes and

the added 8th are included in **Table 2.3** below (Melton, 2005).

Table 2.3 The 7 wastes including the additional 8th waste

1	Overproduction	Products produced without customer demand or processes implemented with no value addition
2	Waiting	Large process inventories incur that processes wait for each other. Products awaiting paper work or release
3	Transport	Repetitive movement of product and raw materials
4	Inventory	Working capital is locked up in high levels of warehouse inventory
5	Over-processing	Duplicate steps and multiple passes for material in order to ensure correct quality
6	Motion	Transporting papers, tools and samples waste time and no value is directly added to the product
7	Defects	Reworking required or temporary installations that need to be redone
8	Talent	Losing ideas and solutions by not engaging the employees (Liker, 2004:29).

- Flow

  This principle is also one of the initial concepts that move away from batch and queue systems to ones with continuous flow. Melton (2005) is of the opinion that it is the hardest Lean concept to understand. One piece flows through the process instead of creating inventory that goes through in batches, as is the case in mass production.

- Pull

  The Lean “pull” principle is centre to eliminating waste from manufacturing plants. The product is produced only on the demand from the customer and therefore pulled, instead of the conventional “push” systems, where the customer’s needs are estimated. Understanding the concept is easier when you look at the function of a supermarket as an example, where customers load only what they need. The

supermarket does not push the various products to customers based on planning and estimating their needs (Eaton, 2013:47).

- Kaizen

  This is the Japanese word for continuous improvement and is based on incremental improvements over longer time periods. The key is low risk and low cost improvements. According to Masaaki Imai (2012:3), the essence of continuous improvement includes the plan-do-check-act (PDCA) and standardise-do-check-act (SDCA) cycles. Systems that need to be in place for effective Kaizen strategy, include the following (Imai, 2012:7):

Utilities

- Value Stream Mapping

  The value stream encompasses the activities an organisation conducts in order to deliver on customer demand. The streams represent the flow of material and information. Mapping of these flows is done for the current state of the process, after which a future state is designed, which establishes the direction for improvement. This tool enables visualisation of complex systems so that work flow, pull factors, and other waste can be identified (Martin & Osterling, 2014:4).

- Kanban

  Pull system for inventory as and when it is needed. Sometimes it refers to Kanban cards or bins. A manufacturing plant consisting of different processes will have inventory or buffer levels in-between. Kanban systems base the inventory on the "pull" of the next process (Baynat, Buzacott & Dallery, 2002). This can be a two-bin process or by means of cards that initiate the pull once the indicator is triggered. It is demonstrated effectively in cell manufacturing where one product gets completed through different processes. Kanban is focussed on preventing over production and waiting in-between process steps.

- Standardisation of work

  In order to realise low variation in product quality cost and delivery, it is required to implement standards which are continually improved. This activity is part of Kaizen and sometimes entails the translation from engineering standards to practical operator procedures and the need to be logical (Imai, 2012:19-20).

- 5S

This activity is intended to create a visual workplace to reduce time searching for items or information. It results in lowered risk since employees are informed and frustration is lower when tools are easily found. It consists of five steps of which each “S” represents the original Japanese word:

- Seiri (sort) – remove unused equipment, prevent clutter;
- Seiton (set or simplify) – logical arrangement and visual labelling;
- Seiso (shine or sweep) – cleaning is essential in waste management;
- Seiketsu (standardise) – colour coding and identification of non-complying physical standards; and
- Shitsuke (Sustain, self-discipline) – audits, enforcing standards (Eaton, 13:144-146).

2.5 Lean in South African mining

Respective organisations implemented a business strategy in 2010 that already had strong synergies with Lean principles. It consisted of standardised tasks incorporated into a maintenance system similar to TPM. It included the transformation of safety (leadership and accountability) and implementing a “system for people” (performance measurement and other people related skills) that can relate to the “respect for people” component from TPS. The emphasis was shifted towards planning, scheduling and proper resourcing, according to a schedule. There is a significant portion of statistical process control and continuous improvement initiatives that were implemented as measuring, analysing and improvement systems; with various levels of success achieved and still being achieved. The implementation was conducted company-wide and on a global scale (McAlear, 2005).

Other unused concepts in Lean were also explored in this dissertation for potential implementation on the shop floor, since most of the interventions were focussed on skilled levels and higher. Numerous systems overlap with the general principles of Lean, but it is the simplicity of Lean tools that can be a key factor in this application. Currently the attention of employees is consumed with negativity. They are concerned about the industry and job security. It is the task of management to focus on the controllable aspects of the business, in order to assist the organisation and to lead the employees into believing in these aspects, as well as to ensure that less time is spent on the external environment, which is out of the company’s control. Lean does just that, with focus on waste elimination

and value creation that can be applied within any department down to the ground level, because of its simplicity (McAlear. 2005).

According to Liker (2004), the elimination of waste and continual improvement are essential parts of the Lean Manufacturing concept, which became known in the 1990's, and originated from studies of the Toyota Motor company. Lean principles have been applied in the resource and processing industry, which reduced wastage effectively across operations. According to Dunstan, Lavin and Sanford (2006), Lean Manufacturing compliments existing business improvement programs and in their example, achieved quick results with productivity and efficiency improvements on processing plants and mining sites.

The questions are what "Lean-waste" is, and why would a processing plant be a perfect place for it to develop and flourish; and how a processing division of a global company, within South Africa, in the business of extracting and producing gold, could stay competitive in current times. These might seem to be trivial questions, but in the absence of direct product competition, control of product price, and with no direct interface with final customers, how would the required pressure be sustained to ensure the optimal use of resources?

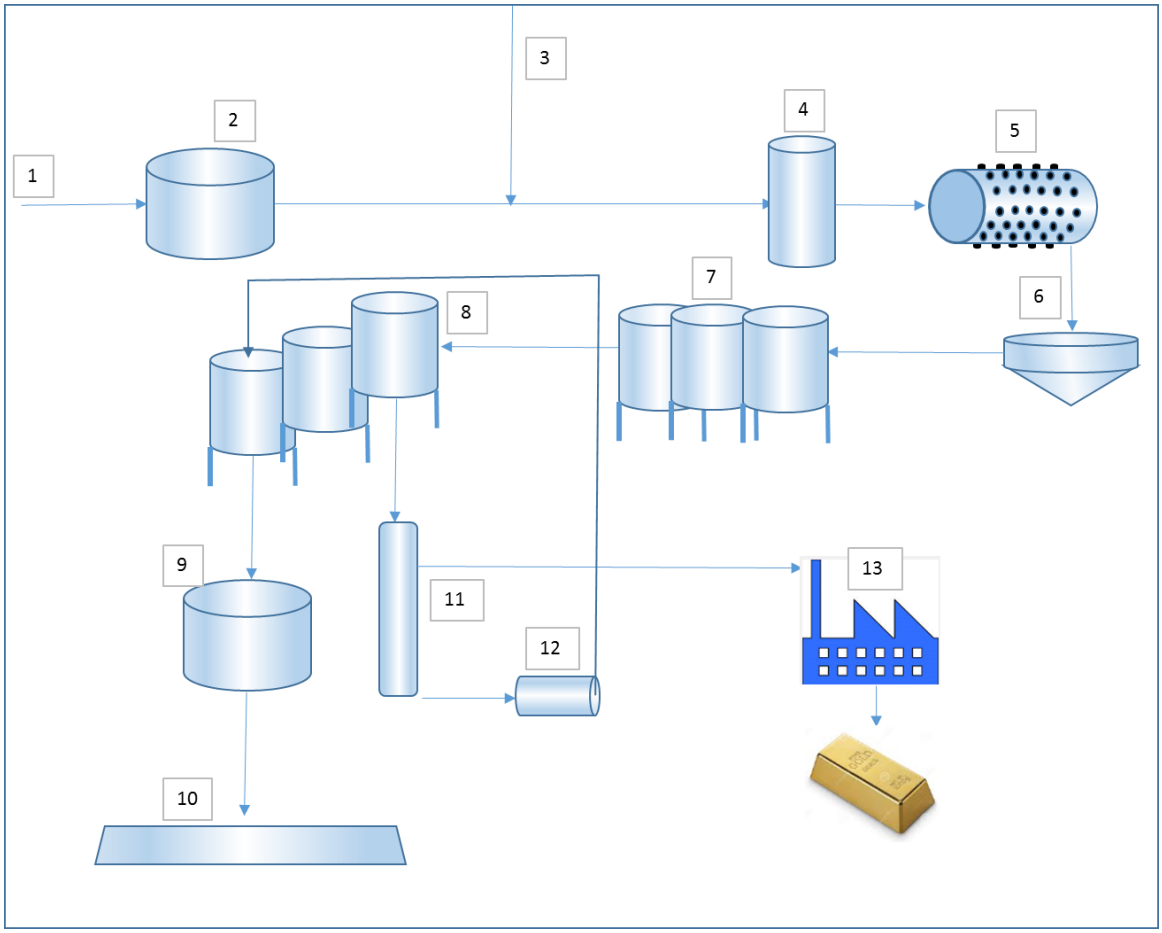
According to Womack and Jones (2003:15), the word muda is Japanese for "waste" and includes all the activities within a business that are "non-value" adding. According to Womack and Jones (2003:15), the antidote to muda is Lean Thinking. It is not a difficult concept to grasp and all people in organisations would recognise it once they know the different types of waste to look for. It might be called different names throughout the world, but all of them have a common golden thread that is linked back to bottom line value creation and waste elimination.

2.6 Gold processing plant process description

Numerous gold plants were commissioned in the 1980's when South Africa was still the leading gold producer in the world, producing 30% of the world's total in 1989 (Marsden & House, 2006:12). The gold processing technology improved significantly between 1960 and 1980, when complex solid separation followed by Zinc Precipitation processes were replaced with more simplistic and cost effective Carbon in Pulp (CIP) and electro-winning processes (Bosley, 1987:331). Since then, the mining reserves in South Africa have

dwindled and it is now only the 5th largest producer behind China, Australia, USA and Russia, with a projected 170 tons for 2014 (Jamasmie, 2014). The gold plant flow sheet is illustrated in **Figure 2.2** below, followed by a full description of the process. In order to create a value stream map in the next chapter, a thorough understanding is required of the gold plant processes. In terms of the scope for this dissertation, the limits will be from where the rock (gold bearing ore) material enters the plant up to the point where the material exits the plant to the tailings storage facility.

Figure 2.2 Conventional gold plant flow diagram



Source: Researcher's own

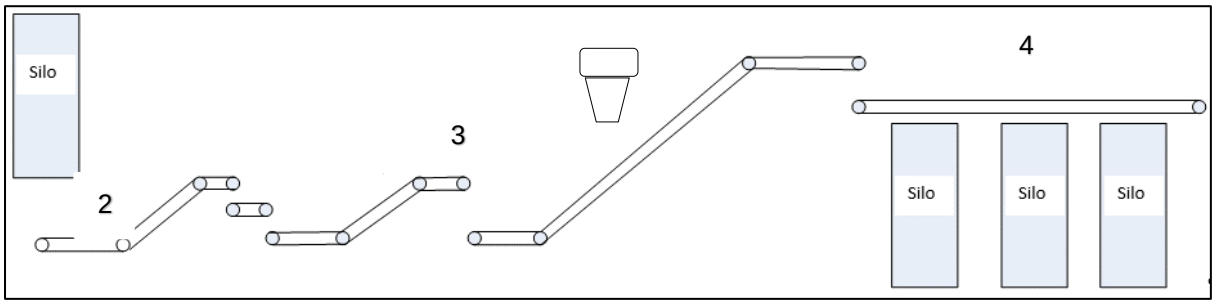
The plant can be dived into four sections, namely ore storage and transport, milling, treatment and recovery.

Sections 1-4: Ore Storage and Transport (Anon., 2014)

1. Description - at this point the gold bearing ore is received from the mine, where it is hoisted from the underground mine by means of skips, and discharged onto a conveyor belt that transports the material to the plant.

2. The storage silo for the ore from the mine is the first structure within the control of the gold plant. It is there to create buffer capacity for the conveyance processes, in order to limit the amount of required stops and starts.

Figure 2.3 Section 1-4 Ore Storage and Transport



Source: Researcher's own

3. There is also an alternative feed source from the waste rock dump. This is utilised in order to fill the plant to capacity in the event of a shortfall from the mine. This material is transported into the plant by means of articulated dump trucks and tipped onto a stockpile. From the stockpile it is loaded as required, by means of a front-end loader onto a conveyor system.

4. The ore is conveyed into another set of storage silos from where it feeds the milling area.

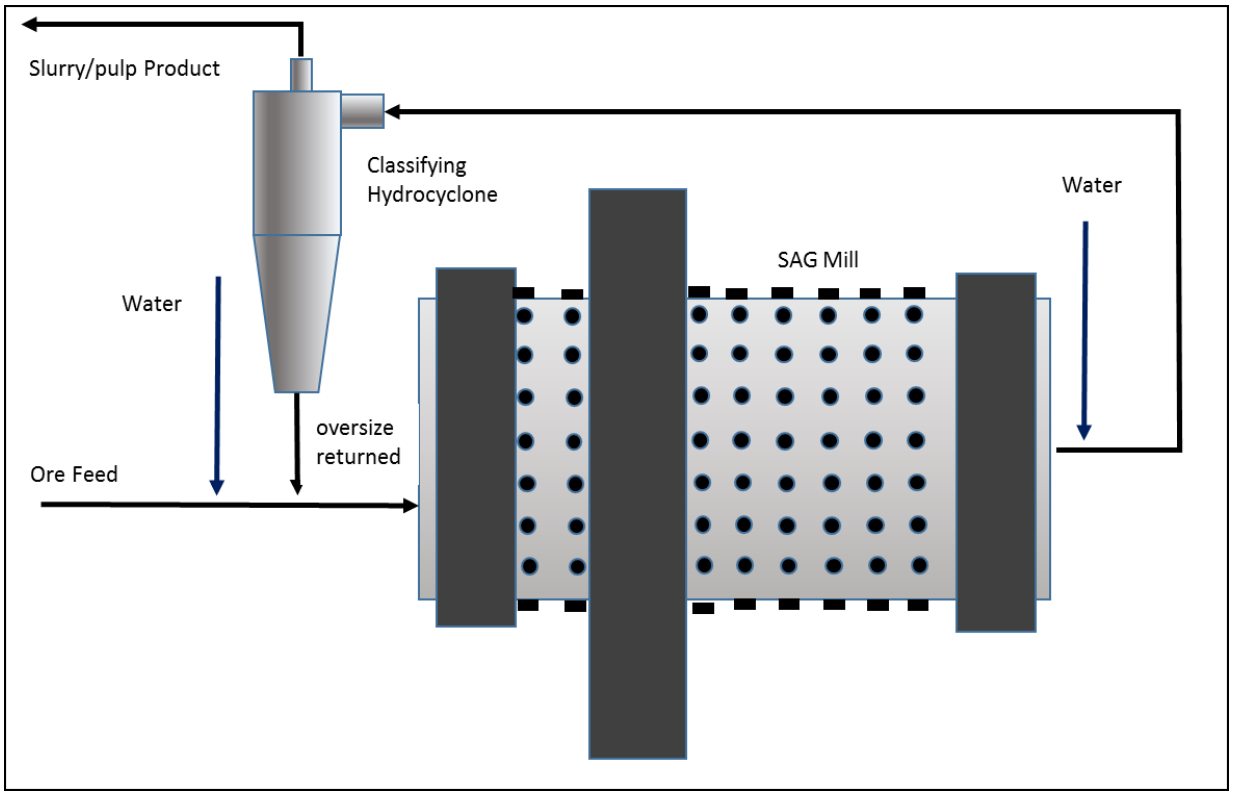
Section 5: Milling

5. From the storage silos the ore is discharged through feed-chutes at the bottom onto another conveyor belt. The speed of this conveyor belt is variable and can speed up or down, according to the need of the mill which it feeds. There are three semi-autogenous mills (SAG) installed and the primary focus of these units are to reduce the size of the material in order to liberate the gold particles. According to Napier-Munn, Morell, Morrison, and Kojovic, it is fairly common in South African milling circuits to use a single stage SAG mill in a closed circuit with a classifying cyclone to produce the final product size (Napier-Munn *et al.,* 2005:160). The maximum feed sizes for these mills are 250mm and the

product specification is that 80% of the product particle size must be finer than 0.075mm and 99% finer than 0.15mm. Gold particles in the reef are very fine and its surface area needs to be exposed so that it can make contact with the chemicals introduced in the treatment section.

In **Figure 2.4** below it can be observed how water is added to the ore and results in a wet milling process. The water serves as a transport medium and renders the product into a state that is called slurry or pulp, which can be pumped. The slurry is pumped into a hydro-cyclone where the ore particles are subjected to centrifugal forces to commence the size classification. The fine material reports to the overflow and proceeds to the treatment section while the coarse underflow is returned to the mill for further grinding, resulting in a circulating load (Napier-Munn *et al.*, 2005: 310).

Figure 2.4 Section 5 SAG milling circuit



Source: Researcher's own

Section 6-12: Treatment

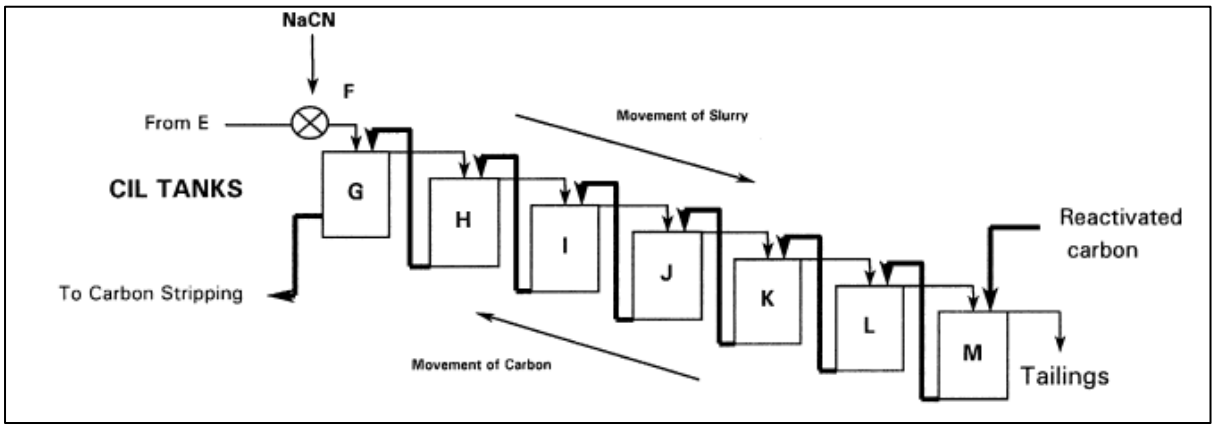
6. The slurry from the milling section gravitates to the thickener section. The thickeners are large diameter vessels with conical bottoms. Due to the low solids to liquid ratio (needed

for effective size separation in the hydro-cyclone at milling) of the slurry, the volume needs to be reduced now prior to treatment with cyanide. A flocculent is added which coagulates the solids and settles to the bottom of the conical thickener. Clear water overflows and is re-used in the milling process. The thickened slurry is pumped from the bottom to the next stage. In the thickener section the percentage solids is increased from 20% to 55%.

7. The leaching stage consists of an array of tanks in series. The slurry flows from one to the next. The pH of the slurry is raised to 10.2 by means of the adding of slaked lime. Liquid cyanide is added to the slurry as a lixiviant, together with oxygen, to leach the gold out of solid state by means of diffusion (Marsden & House, 2006:233). Cyanidation remains the most economical method for the leaching of gold and silver. The tanks in series provide residence time for the reaction to take place. At the end of the leach stage, 96% of the gold is in solution.

8. The slurry gravitates to the next set of tanks, named the CIP, where it is brought into contact with activated carbon particles. The carbon flow is counter current (**Figure 2.5**) to the slurry flow and inter-stage screens prevent the carbon from flushing back again. Thus slurry flows from tank 1 to tank 8 while carbon is pumped upstream in stages from tank 8 to tank 1 (Mular *et al.*, 2002:1644). The pumping of carbon is a batch process which is manually initiated and controlled according to concentration levels. The slurry moves on to the residue section and the carbon is pumped in batches to the elution stage.

Figure 2.5 Section 8 Cascade CIP circuit



Source: Rees & van Deventer (2000)

9. In

During the residue stage, the slurry is captured in large buffer tanks before it is pumped to the TSF. The pump station consists of large centrifugal pumps that are situated in series to enable pumping over great distances to the TSF.

10. The TSF is where the slurry is deposited in steps on a designed TSF. This is either rehabilitated or re-worked in the future.

11. The elution process or “de-sorption”, is the stage where the adsorbed gold is stripped off the carbon and returned to a solution, by reversing the adsorption equilibrium kinetics. Carbon is accumulated into a batch that is transferred at once into a pressure vessel or “elution column”. The column is brought to an operating temperature of 120^0C and then soaked in a 2% caustic and <1% cyanide solution. The pregnant solution is displaced with soft water and stored in a solution tank (Bailey, 1987:493). The process takes up to 16 hours for one batch.

12. After the elution process is completed, the carbon is reused, but first it is reactivated in rotary kilns at 700^0C. This is done to burn off all organics that might be blocking the pores of the carbon, thereby reducing its adsorption capability (Bailey, 1987:530-531).

Section 13: Recovery

13. The solution batch produced in step 11 is transferred into the smelt house. Here it is pumped through electro-winning cells where the gold-bearing solution is subjected to high current, low potential. The cathode is made of stainless steel wool to increase the surface area for gold adherence. The auro-cyanide anions are attracted to the cathode, while hydrogen gas evolution takes place at the anode. After a cycle of 12 hours the gold in the solution has precipitated onto the cathodes (Bailey, 1987:551).

Twice a week the cathodes are removed manually and cleaned with high pressure water. The gold “sludge” is removed from the cathodes into the filter press feed tank. The water is pressed out of the sludge by means of a filter press. The concentrate is dried and oxidised in calciner ovens. The more impurities associated with the gold, the more important is the calcination time and temperature for oxidation (Marsden & House, 2006:454). The flux material is mixed together with the concentrate and smelted in a pre-heated induction furnace. Gold melts at 1064^0C and the impurities oxidise into the slag that floats on top. The molten material is poured into moulds that are arranged in cascade formation on a trolley. The gold remains in the mould and the slag overflows into a collection pan. The

bullion bars have a purity of up to 90% of which silver remains the main contaminant. From here it is sent to Rand Refinery, where the bars are re-smelted and refined to 99,99% purity (Marsden & House, 2006:459).

2.6.1 Implemented principles in line with Lean Manufacturing

The organisation embarked on a business system implementation in 2010 which has similarities with Lean Manufacturing. The system is compared to the following aspects of Lean:

TPM – The system consists of standardised methods of work management. Work consists of works-orders that focus on preventative maintenance as well as corrective maintenance. These orders are then fully resourced with the spares required, planned and scheduled on a plant schedule in order to have a standard and systematic approach to work (McAlear, 2005).

DMAIC and SPC: These respective control measures were identified on the plant and its output displayed on statistical charts, which are web based. Some are real time measurements necessary for control with short update frequencies, while others are lagging behind, as these are the actual outcome of the control measures and provide the information on the efficiency of the control. The control charts are analysed and continual improvement actions are initiated, in order to reduce variation in the process. Action plans are implemented according to a schedule to realise the improvement. The sustainability of the improvement is monitored and re-evaluated at a suitable future date (McAlear, 2005).

Respect for people – The people-aspect has also been considered in a section of which the Human Resources (HR) department became the custodian. The process includes management aspects such as performance management, talent pool development (succession planning), managerial leadership programs, and people engagement.

Safety Transformation – Additional leadership courses and safety program implementations have been applied based on the latest trend within the safety discipline. The ways in which risk assessments are conducted and hazards are identified, received more attention and less complicated templates have been put in place.

The program is extensive and covers all aspects of the business. It is the purpose of this dissertation to illustrate that there are additional Lean Manufacturing aspects which can

support the program already in place. A lot of the current applications do not extend down to the shop floor, and the supervisors and managers are solely responsible for success factors. Some of the Lean utilities can assist with focussing accountability onto the employee on the shop floor. The planning and engaging between the frontline employees and their supervisors are where great value can be realised and waste eliminated.

2.7 Change Management and Organisational Climate

There is an ever present pressure to conduct changes in the workplace, especially as the global environment around us becomes more competitive and process technology advances. The change management is a function performed, and generally conducted by the management of a company or organisation. In the work done by Chetty (2002), the perception of employees regarding the change management process is linked to the organisational climate. The organisational climate can be classified as part of organisational culture, since the work done by Schein in 2004 (cited by Langford, 2009), "have described culture as consisting of values and climate. According to Watkin (cited by Chetty, 2002:17), a favourable working environment correlates with strong business performance, as well as providing evidence that organisational climate impacts directly on the business.

Organisational climate and leadership both affects the implementation of change and therefore how employees react to change (Van Dam, Oreg & Schyns, 2007). The daily work context is where actual changes are implemented within the workplace. It is here where the leader or "change agent" face their followers and also essentially where the change is either successfully motivated or not (Van Dam *et al.*, 2007).

One of the key aspects of Lean Manufacturing is continuous improvement, which constitutes continuous change towards perfection. According to Stone (2012), the Lean literature has a "void" when it comes to literature available on planned organisational change. The characteristics of the change process are what enhance the employee acceptance of change, which includes "provision of information, opportunities for participation, and the diffusion of trust in management's vision underlying the change" (Van Dam *et al,*, 2007).

In an article by Patrick Mayfield (2014), he states that organisations frequently make the mistake to tackle change projects by ticking boxes and moving through carefully designed schedules. The high performing managers spend the majority of their discretional time in conversations with employees, where they have discussions with purpose. People can be influenced by first listening to their thoughts and then be sympathetic when expressing their fears. Provide employees and colleagues with the opportunity to highlight their aspirations with genuine interest, because you are open to different viewpoints in the change that is considered. The barriers to change can be effectively addressed with this approach (Mayfield, 2014). If there was no change in the workplace then management and workers might have been all that was required, but change requires leadership, since people will always be affected and disrupted.

The literature on change management is extensive and organisational development (OD) practitioners have become more involved with organisations to facilitate interventions through means of social and communication tools. They are assisting modern companies to face competitive demands. The consultant's focus is mainly on relationships between management and employees, sometimes utilising psychological and strategic management to achieve the desired intervention (Cummings & Worley, 2009). The desired change agents for implementing a complete Lean Manufacturing project will benefit if they have similar skill sets, in order to make their relationships a central part of the project.

With regard to Lean Manufacturing, the literature on "respect for people" is limited, which is the second leg of Lean Manufacturing. Dr Jeffrey Liker dedicated a section in his book to this portion (Liker, 2004:172). After studying the Japanese motor industry for 20 years, he developed an appreciation for how this portion is entrenched in the way that the Japanese conduct their business. Toyota promoted their leaders from within the company, after spending years to the understanding of and learning the TPS (Liker, 2004:172). This is against the trend of other USA auto manufacturing companies, which import leaders who then implement multiple changes in order to boost the sales and productivity. This method in itself can contribute to employee resistance to change management - employees could be unwilling to drive new initiatives hard if they know that the system will change in the near foreseeable future.

Toyota does this because of the importance of creating future leaders who understand the TPS, and who can teach it to other future leaders in turn. This increases the depth and

loyalty of employees, as there is true succession and sustainability in the views and processes of the company (Liker, 2004:173).

According to Jackson (2013) the elements of climate include:

Decision making:

Being involved in the decision-making process that affects them;

Communication effectiveness:

Entails the quality and the correctness of information flow upward and downward;

General motivating conditions:

The existence of a friendly atmosphere and the quality of human relationships;

Quality of the physical work environment:

Resources and equipment necessary for work;

Goal clarity:

The organisation has clear direction and knows where it is heading;

Interest in the well-being of employees:

The care for people as human beings;

Co-ordination:

Cross departmental support for one another and the way in which work is planned and executed.

Once the organisational climate is measured it can be used to influence behaviours and to improve relationships. This is recommended to evaluate the effectiveness of prior implemented changes, as well as in preparation for new changes that are endeavoured. In the work by Kelner *et al.* in 1996 (cited by Klem & Schlechter, 2008), the “climate of an organisation is directly linked to the actions of the leader”.

There are several critics of organisational climate surveys, as some authors recommend that such a generalised climate can only exist if the variance in psychological climates (individual) was lower within the groups than between different groups (Guion, 1973, cited by Langford, 2009). The survey of the general organisational climate still adds value in

terms of providing general direction for improvement initiatives. The generalised survey provides the platform for benchmarking against other organisations and also provides specific outcomes for future improvement (Langford, 2009).

2.8 External factors affecting the South African mining sector

According to Harvey (2013), the South African mining industry has been contracting by 1% per year from 2001 to 2008, whereas the top 20 competitors grew at an average of 5% per year. This is despite the fact that Citigroup valued South Africa's in situ mineral resources as the largest in the world, at a value of $2.5 trillion. Policy uncertainty has contributed to this poor performance in a time when other countries were expanding rapidly during the commodity boom. It further stipulates restrictive labour legislation and an unqualified labour force as the primary obstacles for doing business in South Africa.

In 2012 there was a wildcat labour strike that spilled over from the platinum sector, and was caused by the relatively small union, the Association of Mineworkers and Construction Union (AMCU), challenging the dominance of the long serving National Union of Mineworkers (NUM) (Smith, 2012). This followed after a strike by the same union in the platinum sector that resulted in the death of 34 miners at Marikana.

The reason for combining the survey of change management's causal effect on the organisational climate, together with a proposed optimisation program such as Lean Manufacturing, is partly due to the historical past of labour in a mining sector as unique as South Africa's. It is important to measure the perception of employees prior to recommending certain changes, especially if the indication is a strong resistance to change. This is an important aspect to explore in terms of context, when explaining the need for change management, as well as obtaining employee trust and the building of strong relationships. The Japanese "respect for people" from the TPM and employee engagement might very well become a prerequisite recommendation for the implementation of complete Lean Manufacturing systems.

In an article by Hartford in 2012, he perceives that mining employees are being alienated from the line management since supervisors have relinquished the "people management" portion of their work. He further ascribes this alienation to enforced transformation processes and a heap of new labour legislations, which forced the supervisor to become a

production and safety functionary alone. This resulted in leaving the people issues for HR and unions to resolve, leading inevitably to relationships being damaged.

The South African mining industry is burdened by the firm economics of being commodity price takers, influenced by the exchange rates. The fixed cost portion is relatively high with labour contributing up to 50%. This leaves the industry very few levers to pull in order to improve competitiveness (Hartford, 2012). Exploring the current South African labour statistics form Statistics South Africa (Statistics South Africa, 2014), it is evident that unemployment is thriving at 25.2%, with the total active labour force estimated at 20.122 million. Together with low economic growth, it places the mining sector under severe pressure as one of the main employers in the country. This is not only true for South Africa though, since the gold industry has a long history of attracting large numbers of migrant labour from neighbouring countries. All these factors, together with a declining industry, provide the grounds for long periods of industrial action as a result.

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Chapter 3 **Research methodologies: Empirical and experimental.**

3.1 Introduction

In this chapter the method of the research is described and explained. This dissertation will venture into more than one type of research methodology since the objective is to recommend implementable Lean Concepts based on experimental data and practical studies. Since Lean Management is all about embracing continuous improvement changes, together with the respect for (and of) your employees, it is imperative to measure the perceptions of the employees regarding change management in the company climate. Change management might be perceived as a threat to employment, and therefore be resisted or perceived positively by providing renewed hope. The questionnaire will provide insight into these phenomena.

Lean Manufacturing does not only bring about changes and introduce new work systems, but it is also about the people and the associated leadership practices. The way in which employees are treated, developed, measured and motivated, will depict the success of the proposed changes, since it will be the employees working with it. Therefore the measurement of the employee perceptions regarding organisational climate can provide critical insight if management would be implementing changes alone, or as a collective team.

3.2 Research approach

Qualitative study

The processing plant will at first be illustrated by means of a current state VSM from which waste and restricted flow is identified. Once identified the interventions will be treated as implementation projects for which a financial justification is conducted with actual data obtained from operations in order to analyse the potential benefit which is presented. Another VSM will be drafted later on, which should form the basis for continuous improvement initiatives. The applicability of the VSM tool across the various existing systems will be incorporated, such as its potential to serve as part of the required documents for change initiatives that require expenditure or project justification.

Quantitative study

The employee perceptions will be measured by means of a questionnaire, adapted from the work conducted by Chetty in 2002. The objective is to quantify different perceptions of employee groups regarding change management and organisational climate. This portion of the research falls within human behavioural sciences and the questionnaire will aim to provide numerical data that could be subjected to statistical analyses. The reliability of the questionnaire will be tested by means of calculating the Cronbach alpha coefficients.

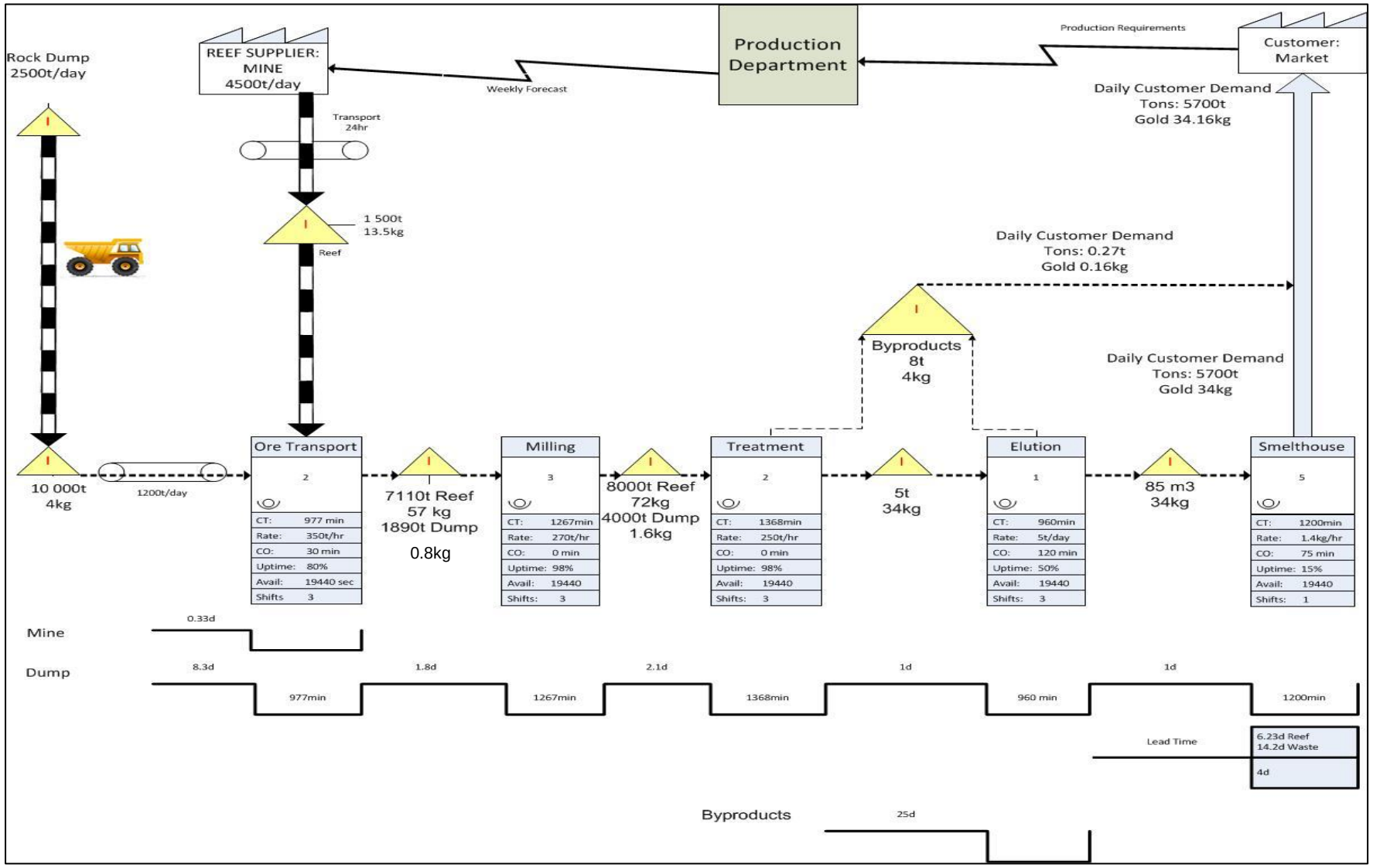
Applicable recommended Lean Manufacturing tools which have proved to benefit similar industries in relevant case study literature, have been identified. The practicality and applicability within the respective processing plants will form part of the research. The tools will be tried and tested, where possible, in the plant in order to come to a conclusion, with the respective employees, regarding its applicability and potential value.

3.3 The current VSM as baseline for the processing plant

The current VSM was constructed with the assistance of metallurgical staff and is illustrated below in **Figure 3.1**. In the current VSM, the flow of the material starts with the sources of gold bearing material, namely the mine shaft (high grade reef) and waste rock dumps that are reclaimed to fill the plant capacity gap. The reef material grade currently is at 9 grams of gold/per ton of reef (9 g/t), while the waste rock dump material is at 0.4 g/t. Throughout the VSM the storages are expressed in tons and gold quantity since the grade increases throughout the process as a result of concentration.

Within the ore storage and transport section, the loading of both materials into the plant are batch processes, since there are changeover times involved and deliveries proceed according to a schedule.

Figure 3.1 Current state VSM



Source: Researcher's own

The reef material is stored in a silo with a 1500 t capacity and the rock dump material on a stockpile with 10,000 t capacity. From here it is mechanically fed into the plant, at a maximum transfer rate of 350t/h, by means of conveyor belts, into another set of silos with a total buffer capacity of 10,000 t. These silos represent inventory within the VSM, and serves as buffer capacity for the continuous flow processes that follow.

The milling section is a continuous process in which the raw feed material size is reduced, in order to liberate the precious metal. The throughput rate is 85t/hr per mill and there are three installed in parallel, providing a total throughput of 255t/hr. It is a wet process, since water is introduced as a transport medium to enable transfer by pumping. These units are power intensive and therefore need to be fed constantly in order to prevent the wastage of electricity, which accounts for 25% of the overall fixed costs of the plant. The milling equipment is the largest single-unit equipment on the plant and the availability and utilisation thereof is crucial for effective production rates and efficiencies. Waste elimination or improvement initiatives in this section can hold great potential that may significantly impact on overall plant production.

In the treatment section, the liberated mineral is subjected to chemicals in the presence of oxygen, in order to dissolve the precious metal by diffusion. The required residence time allows for maximum extraction efficiency. The time aspect of this section can be optimised with improved diffusion kinetics. This opportunity is already part of current research for improvement and will not be mentioned for improvement in this value chain analysis.

From the treatment process, the next concentration process is the elution section. This process was designed as a batch process by the Anglo American Research Laboratory (AARL) in the 1970's (Bailey, 1987:493). The result of the sequential steps in the process is highly concentrated gold in a relatively small volume of eluate solution. This solution is pumped as a batch to the smelt house, where a series of batch processes are housed; from electro-winning to the actual smelting of the gold concentrate, resulting in the final product.

There is another flow emanating from the treatment and elution sections, which is the by-product stream. The product is still gold, but in small quantities, trapped together with undesirable materials that cannot be treated in the conventional process. Improved removal of these by-products improves overall process efficiency

of the main plant. This section is regularly overlooked with regard to importance of availability and utilisation when compared to the main production units. Examples include organic material, such as woodchips, that accompany the ore received from the mine, which is floated off and screened out for separate recovery. The pumping of carbon in the treatment and elution sections, results in the generation of carbon fines as the material breaks down due to abrasion. These fines are removed by means of screening which results in a lucrative by-product that may generate significant revenues. The by-products are collected and then transported in batches for off-site treatment and refining.

The deliverables for the VSM include:

1. Current VSM with opportunities indicated
   Illustrating the current plant flow sheet as it is now. This map is stored as a baseline which can be referred to at a future date.
2. Desired future VSM
   The proposed changes according to the principles are brought onto the map. After implementations, this map should form the current VSM for future initiatives. Therefore it is advisable to save revisions as improvements are completed.

3.4 Employee perception survey

The questionnaire has been distributed across different disciplines and work levels within the processing department, across two of the processing plants. The objective was to measure perceptions concerning the management of change and its perceived effects on the organisational climate. These perceptions could influence future project implementations negatively, irrespective of the positive value potential. The quantitative research results will provide insight into this dynamic social aspect and recommendations on its importance and perceived impact will be made.

The quantitative research will be conducted according to work by Chetty (2002), that defined the dependant variable as “Change Climate” and the independent variable as “Change Management”. The climate towards change, within an organisation, correlates with management’s success of implementing changes. Clear and transparent leadership by managers is estimated to contribute up to 70% towards

the established climate (Chetty, 2002). Once the climate is measured, it can serve as a valuable tool for management, since it can be addressed timeously. The climate can be adapted and changed, while a company "culture" is more difficult to alter. The difference being that the climate is based on the perceptions and the attitudes of employees, while the culture consists of beliefs and values that have been established over time (Jackson, 2013).

3.4.1 Survey sample

The sample was taken from two gold plants, located geographically within the Gauteng Province, belonging to the same company. The aim was to obtain a sample across the different disciplines and work levels from both gold plants, in order to conduct the statistical analysis and apply the data to the processing plant population in the statistical conclusion. A sample is the portion of a population that is selected for analysis (Levine, Stephan, Krehbiel & Berenson, 2011:34). The questionnaires were distributed randomly, and the objective was to obtain a return of more than 100 from the 180 distributed. The respective number of employees for the two selected processing plants was 170 and 316, and the sample of 100 represented a minimum of 20% of the total. The population data was obtained from the human resource department and is illustrated in in **Table 3.1** below. Female representation is lower in general within the mining industry and has been a focus area for Human Resources for a while now. The male representation for this study was 83% while the female participants constituted 17% of the total. The sample selection was done randomly by distributing the questionnaire to employees available on the e-mail address book and manual distribution through the supervisors from the different disciplines. The manual questionnaires were distributed through the line supervisors to the respective operators. An attempt was made to distribute the questionnaires throughout the relevant job levels within the processing plant.

Table 3.1 Target population of the survey

	Category	Frequency	Percentage %
Total Employees		486	100
Gender	Male	404	83
	Female	82	17

Ethnicity	Black	421	87
	White	58	12
	Coloured	6	0.8
	Indian	1	0.2
Age Distribution	20-29	68	14
	30-39	139	28.4
	40-49	146	30
	50-59	130	27
	60-65	3	0.6

3.4.2 Validity and reliability

This particular dissertation covered both physical science and behavioural science. The first part was based on physical science and practical applications developed from recommended projects originating from the current VSM, based on the actual measurements of mass, concentrations and financial requirements. The actual data did not require validation, since it was based on authentic experimental values. The second part of the research survey was based on the behavioural science approach, for which there are no absolute answers. The reliability of the data was therefore imperative to the research. According to work by Stainback in 1984 (cited by Welman, Kruger & Mitchell, 2011), quantitative research is more focused on reliability where the consistency and stable measurements of data are important. With qualitative data, the validity is considered more important, as the objective of the study must be representative of what is being investigated.

Construct validity is the “degree to which the instrument measures the intended construct rather than irrelevant constructs” (Welman *et al*., 2011: 142).

Welman *et al*. (2011:145) state that “if a research finding is repeatable, it is reliable”. Reliability can be tested by means of applying some of the following tests:

Re-test is where the same survey is given to the same sample at a different time in the future to determine consistency in the answers provided. Too much time in between can result in inaccuracy, since actual changes could have influenced the way in which questions were answered. Too little time in between surveys may

prompt the exact same answers, due to memory recall, which defies the purpose. Correlation coefficient for the two data sets provides the index for reliability (Welman *et al*., 2011:146).

The parallel test requires different questions into the survey, while the objective remains the same, thus prompting a consistency in the outcome. It poses the same challenges as the re-test, which is to get enough participants to complete another set of survey documents.

Internal consistency is a statistical reliability coefficient that is applied to the results obtained from a single survey. The inter item correlation is calculated for each item with every other item. The average provides a relative score, reflecting the reliability of the measuring instrument. According to Huysamen in 1989 (cited by Welman *et al.,* 2011:147) the coefficient is called Cronbach's coefficient alpha. This particular coefficient was used in the research for reliability purposes. Cortina (1993) emphasises that the coefficient alpha implies that, on average, the split halves of the test are highly correlated, and that it does not imply the degree by which a construct is measured. Cronbach's coefficient alpha would therefore indicate whether the test measures something consistently, but does not provide meaning for the measure (Cortina, 1993). A Cronbach alpha value between 0.6 and 0.7 falls in the lower range of acceptability according to Hair, Black, Babib, Anderson and Tatham, deduced from work done in 2007. Some individual constructs might need to be eliminated, should the coefficient be below the minimum value, in order to obtain acceptable values for internal consistency.

Split-halves reliability encompasses that the sample data is split into two groups and correlated with each other.

3.4.3 Measuring instrument

The measuring instrument was a questionnaire obtained from work completed by Chetty in 2002. The instrument used a Likert scale of 1 to 5 with a score of 1 implying "Strongly Disagree" and a score of 5 indicating "Strongly Agree" at the extreme ends for each question. The first 8 questions evaluated the participants' demographics and work background. Questions 9-18 measured the perception of the

way in which the participants experienced and drove change management. An example followed by a description is provided below:

Question 9: I make comments at meetings on new ways of doing things.

Measuring the drive towards change management and if the participant is a change agent or more conservative in the way that standard work is conducted. Continual improvement entails continuous changes and if the participants are comfortable to initiate changes, the climate might already be positive towards change. In a company where resistance to change is high, people will “give up” raising new ideas, since they never materialise and would probably answer this negatively towards a score of 1.

Lastly Questions 19-29 measured some organisational climate factors which could also indicate whether there is an underlying resistance to change. An example followed by a description is provided below:

Question 19: Employee ideas are encouraged and used constructively by management?

Encouraging employee ideas demonstrate trust in the capability of all employees and by using it constructively, builds respect and desire for improvement. According to Driscoll and Evans (2009), there is required respect for the capability of employees, and by recognising this capability and utilising it within possible opportunities, can build mutual respect, trust and dignity.

The instrument was distributed to both middle management and front line employees on purpose, in order to compile the perceptions from both angles. Middle management is usually involved with implementing changes and taking ownership of change management while the employees at the front line have to work with these changes and is actually responsible for the success or failure of the initiative.

3.4.4 Procedure

The questionnaire was constructed on SurveyMonkey.com (2014) and a hard copy was distributed to the HR department for the relevant approval and authorisation to distribute. An introductory e-mail was constructed that explained the purpose of the survey as well as providing the guarantee that information would be treated

confidentially, and only be used for statistical purposes. The questionnaire was distributed to supervisors across the plant within the production, engineering and services departments, after which a list of their direct employees was requested for approach. Upon receiving the lists, questionnaires were forwarded via e-mail to some, while hard copies were circulated to the rest. Of the total of 115 respondents, 70 submissions were via e-mail and 45 received as hard copies.

3.4.5 Ethical considerations

The questionnaires stipulated on the front cover that completion was purely on a voluntary basis. The questionnaires were accompanied by an explanation of what the objectives and motivations for the survey were. Even though no particulars were gathered from the hard copy questionnaires, the e-mail addresses in the organisation's address book were utilised for the electronic distribution. The potential for a re-test on the physically distributed forms was not possible due to the unknown portion of the participants.

Confidentiality was kept intact and statistical data was gathered anonymously into an excel spread sheet for analysis.

3.4.6 Statistical analyses

The raw data was analysed by the statistical department of the North-West University, using Statsoft software (Statsoft, Inc. 2010). Descriptive statistics demonstrated that the data emanating from the questionnaire in the summarised tables described the sample outcomes. The questions were discussed according to the mean values and standard deviations obtained.

The application of T-tests and ANOVA were done to test the effect of different groups within the sample, according to demographic information. The T-tests were performed on groups, where answers were concentrated into two groups only, namely for gender, ethnicity and job level. The ANOVA analysis was applied where more than two groups were analysed. The p-values and effect sizes were utilised to evaluate the statistical and practical significance of the different groups.

According to Kühberger, Fritz and Scherndl (2014), the p-value is criticised for inferring only "rejected" or "not-rejected" decisions, and the misconception therefore exists that, not-rejected is largely significant, while rejected is not significant at all.

For this reason the effect sizes were incorporated together with the p-values, in order to measure the strength of a phenomenon and provide an estimate of the magnitude of the relationship. It was also referred to as the practical significance. The p-value normally indicates statistical significance for p-values of less than 0.05 (Kühberger *et al.*, 2014). The effect sizes are classed as medium effect for results higher than 0.3, and large effect for results higher than 0.5.

Chapter 4 **Results and Discussion**

4.1 Results and discussion

In this chapter the results and outcomes of the research are discussed, followed by recommendations and conclusions. The results are presented during the 3 different steps that this research has followed, starting with the future state VSM. The Lean Manufacturing principles have been applied to the current state VSM and then subjected to an evaluation and justification to illustrate the feasibility of such implementation.

Secondly the results of the quantitative survey on change management and organisational climate are discussed with the statistical analysis. The perceptions regarding the current practices of change management are analysed and the relation to the current organisational climate is explored. It should become clear from the survey whether the processing plant should pursue with the proposed changes and a sustainable continuous improvement process, or whether the focus should first be on higher engagement levels of employees, in order to build a positive organisational climate. The sustainability of the implemented changes depends on this, since resistance can destroy the potential value of initiatives.

Lastly the recommendation includes the implementation of practical Lean Manufacturing tools. A gap analysis has indicated the corresponding aspects of Lean Manufacturing already implemented by the company, as well as which other available applications might also be considered for value addition, waste elimination or continuous improvement. The results are displayed in **Table 4.1** below. It is evident from this that the company has focussed primarily on the maintenance strategy and Statistical Process Control (SPC) aspects this far. Within a processing plant these make sense, since the availability and utilisation of equipment depict business success or failure as the commodity value is extremely high. In the metallurgical extraction process there are numerous process controls applied in order to extract the desired metal economically and therefore stability (which is a SPC and Six Sigma objective) in the process held the highest potential for significant savings.

The recommended practical Lean Manufacturing tools will be primarily focussed at this level of employee and supervisor. While these are not intended to fix broken working relationships, it provides a platform for both the supervisor and employee to interface and spend time together in order to address process related concerns. Involvement of employees with daily production decisions and changes will contribute towards the second leg of Lean Manufacturing, aimed at "respect for people". These tools are all based on Lean Manufacturing principles and either address waste or increased value.

Table 4.1 Implemented and unused Lean principles

Principles Implemented	Unused principles
Standardised Work / TPM	VSM
Six Sigma/TQM principles	Continuous Flow
Measures and control charts	Kanban - Stores + BOM
Analyse and improve	7 wastes
Statistical process control (SPC)	5S
	Visual Factory
	Heijunka - even work load
	Takt Time
	Employee engagement
	Supplier relationships
	Poke Yoke - stop and fix
	Kaizen - continuous improvement

4.2 Future VSM

4.2.1 Identified opportunities

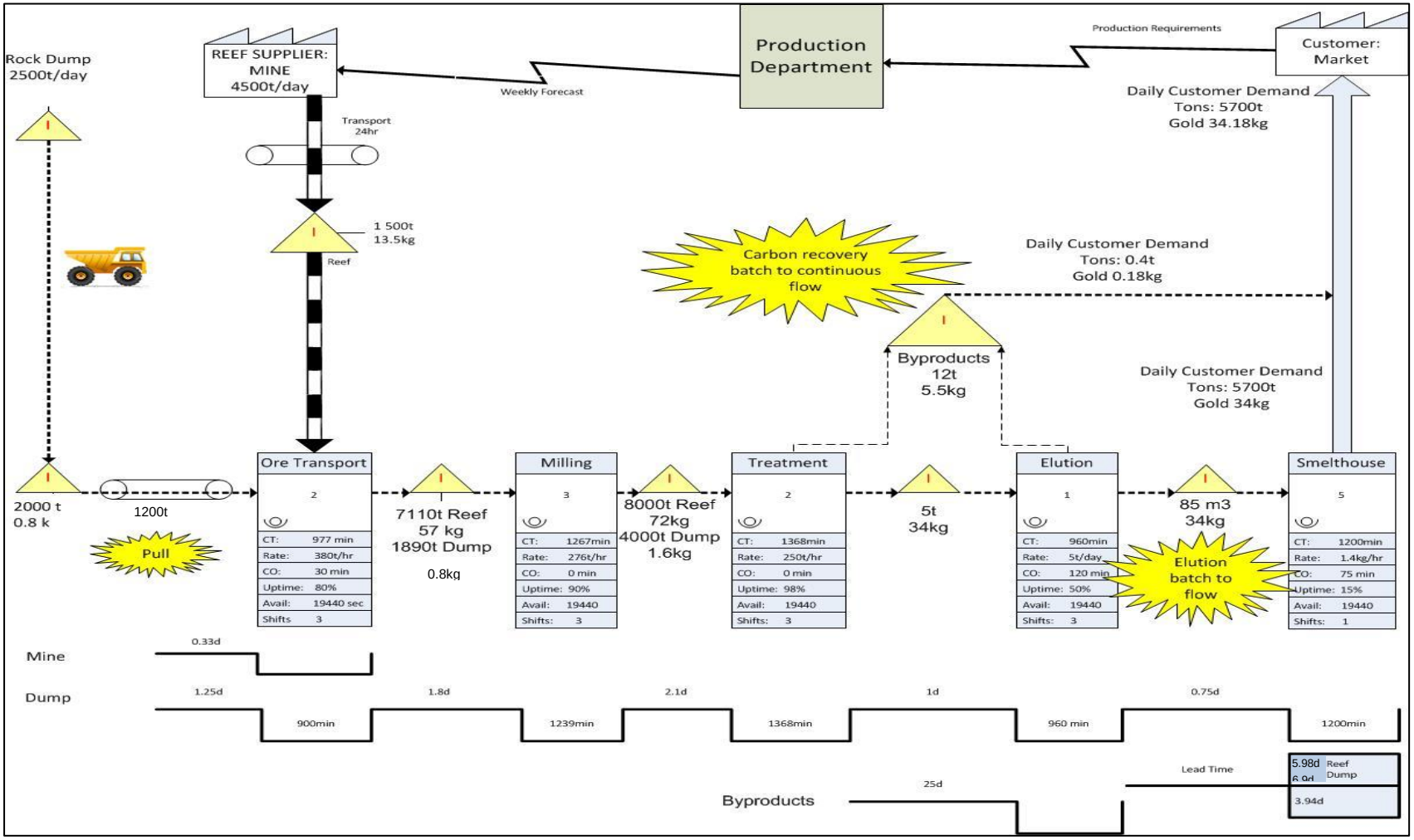
After conducting the future VSM there three opportunities have been identified that add value according to Lean Manufacturing. These proposals vary from material "pull" resulting in lower inventories, to changing batch processes into continuous ones.

4.2.2 Implementing material "pull" at the stockpile

The first opportunity includes implementing material pull with regard to the waste rock dump stockpile. Currently the stockpile level is according to a set amount of 10,000 t and not according to the demand of the plant. The daily demand is 1200 t, and therefore the new level is adjusted to 2000 t, as illustrated by the future VSM on the left hand side in **Figure 4.1** below. This would result in a shorter travel distance for the front-end loader to load material into the plant and leave a smaller footprint for

the stockpile. The shorter travelling distance improves the takt time of the activity and frees up time of the machine, which can be utilised to clean the plant. When stockpiling is 10,000 t in the area, dedicated time is required by the front-end loader to flatten the heap and ensure that trucks can drive onto it to tip material from the top. It also results in fuel saving which can strengthen negotiations with the respective contractors. The plant currently employs a second earth moving contractor that conducts general cleaning around the plant, but is not fully utilised. The opportunity here is to utilise only a single contractor and negotiate a better rate on the plant cleaning work. The second contractor would benefit from obtaining full-time work for the unit in the longer run, instead of the limited cleaning work that it is currently employed for. Implementing a 2,000 t stockpile reduces the lead time from 25 days to 1.25 days.

Figure 4.1 Proposed Future VSM Source



Source: Researcher's own

Table 4.2 Potential benefits for 1st proposed implementation

Decrease Waste rock stockpile size advantages	
1	Decrease travelling time – freeing up time
2	Decreased fuel consumption
3	Time for maintenance – higher availability of equipment
4	Reduce to single contractor – improved rates
5	No stockpile management required

The following section includes justification for the proposed changes and attempts at quantifying the savings potential stipulated in points 1 and 2 in **Table 4.2** above. The exercise was conducted to measure the physical loading time of stockpile material using a front end loader. The front end loader was measured loading the stockpile material back into the processing plant over the course of a weekend. The illustrative photos of the actual loading can be seen in **Appendix 5**. The complete stockpile was loaded back over the weekend, without additional material being delivered, which allowed for the opportunity to measure the complete loading time cycle for small and large stockpiles. For the 2,000 t stockpile position, indicated by the labelled 2,000 t square block in **Table 4.4**, the measured loading time was 29 seconds one way and 58 seconds for the full round trip. When the last portion of the stockpile was loaded, it represented the 10,000 t square block in **Table 4.4,** and the loading time was 37 seconds one way and 74 seconds for the full round trip.

Keeping the stockpile at the 2000 t level therefore has a time benefit of 16 seconds per load between the extreme ends of the stockpile. The volume loaded in one load is 3.5 m^3 and the material bulk density is 1.9 t/m^3. Therefore one round trip transports 6.65 t from the stockpile. Therefore 180 loads are required to load the required 1,200 t/day, resulting in a total required time of 2.9 hrs, without any stoppages calculated in between.

When the stockpile is at 10,000 tons, the loading time increases because of the distance from the feeding bin. Loading the furthest area on the stockpile (indicated with the red arrows in **Table 4.4**), took 74 seconds for the round trip. To load the daily demand of 1,200 t from the furthest point of a 10,000 t stockpile, will take 3.7 hrs.

For comparison, the difference in time of 0.8 hours is divided by 5 in order to increase the loading time linearly, as the stockpile gets depleted and the distance increases.

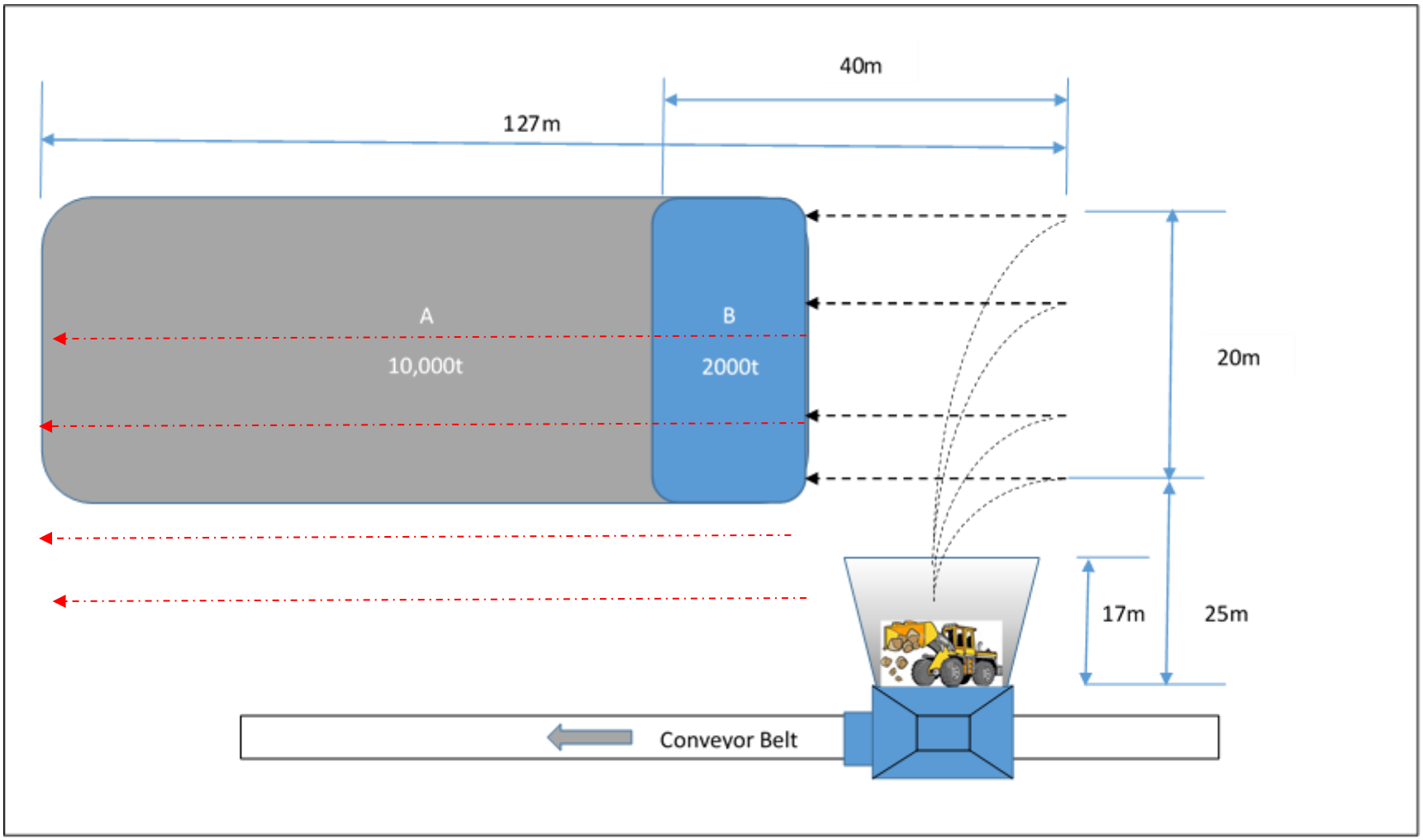
Table 4.3 Loading time comparison between 10 000t and 2 000t stockpiles

Distance from Loading point	Loaded tons	Loading time in hours
1st	2 000 t	2.9
2nd	2 000 t	3.06
3rd	2 000 t	3.22
4th	2 000 t	3.38
5th	2 000 t	3.54
Total	**10 000 t**	**16.1 hrs**
Proposed smaller stockpile of 2,000 t, and loading 10,000 t in total		
1st	**2 000t x 5**	**14.5 hrs**

The total difference when comparing the loading times respectively as in **Table 4.3** above, results in a time saving of 1.6 hours for 10 000 t (16.1-14.5=1.6) of material loaded. The total material demand per month is 36 000 t which equates to a 5.76 hours total difference in loading time. At the current hourly rate for a front-end loader of R505/hour, the potential saving is R2 909 per month in rental. The diesel consumption is 12 l/hour at a unit price of R12.50, which adds up to R864 and results in a R3 773 cost saving.

Even though the benefit value is low when compared to total plant costs, it is exactly what Lean Manufacturing principles are about. Incremental continuous improvement all adds up and impacts collectively. These perceived “small” benefits could be one of the reasons why numerous implementations have been disregarded. These small improvements lead to a snowball effect of efficiency and savings across different equipment, processes, labour, resource consumption and even the carbon footprint. The requirements to implement the required change would consist of dedicated planning, time and communication.

Table 4.4 Stockpile management- reduced inventory effect (own)



4.2.3 Fine carbon recovery circuit: Batch to continuous operation

The next opportunity was to convert the fine carbon removal process from a batch process (operating only during day shift) to a continuous-flow 24 hour operation. Fine carbon is part of the by-product production and contributes currently up to 4 kg of gold per month. By converting this into a 24 hr operation, there will be more opportunities to reduce losses and recover product.

Figure 4.2 Fine carbon removal system (by-product)



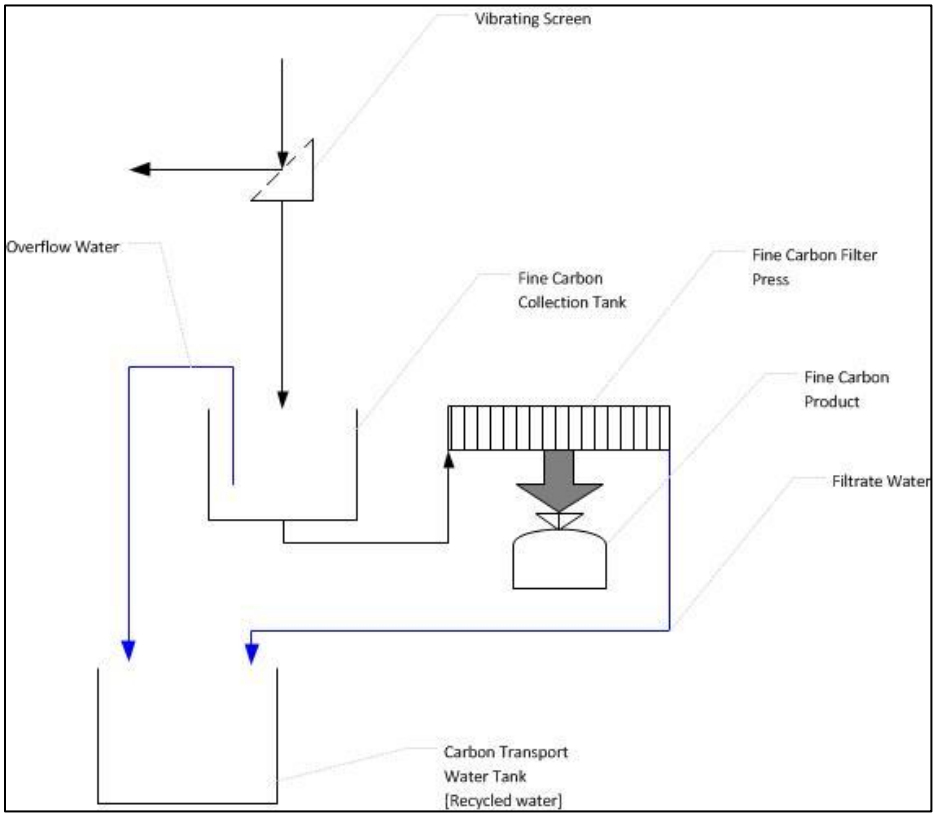
Source?

In the CIP section (illustrated in **Figure 2.5)** the gold in solution-form is brought into contact with activated, granular carbon. The carbon granules are made from coconut shells that proved to have the highest porosity and abrasion resistance compared to other coal types, making it suitable for the gold processing industry (Marsden & House, 2006:301). The dissolved gold absorbs into the porous structure of the activated carbon, resulting in a high gold concentration within smaller treatable volumes. The carbon is transferred to the elution section by means of pumping, where it is subjected to a caustic cyanide solution, elevated temperatures of 120 ^{0}C and pressure to reverse the adsorption reaction and return the gold to a concentrated solution. The carbon is an

expensive reagent and needs to be re-used. In order to restore its activity (affinity for metal anions), the carbon is regenerated in a kiln furnace at 700 ^{0}C. This removes any organic contamination from the surface and restores its ability to adsorb gold effectively. The handling process of the carbon results in fines generation which is screened out prior to returning it into the CIP section. The particles smaller than 0.8 mm are referred to as fine carbon product and removed by means of a filter press, which is illustrated in **Figure 4.2**. The filter press consists of filter media that separates the fine carbon solids from the water, resulting in a carbon filter cake with an average of 25%-30% moisture content.

The flow sheet for the section is illustrated below in **Figure 4.3,** and starts with the vibrating screen that separates the carbon fines from the re-usable carbon. The carbon fines with water then gravitates into a special collection tank to enable the carbon to settle and the water to overflow to the carbon transport water tank, where it is re-used in the elution and CIP circuits. The fine carbon sludge is pumped through the filter press and the filtrated water is also recycled back to the carbon transport water tank.

Figure 4.3 Fine carbon flow sheet



Source: Researcher's own

The current operation, with overflow water from the fine carbon collection tank reporting to the carbon transport water tank, results in fine carbon losses due to carry-over of the suspended particles. These carbon particles also proved to be detrimental to the water pump seals, resulting in a high rate of failure and, in the worst case scenario, the entire pump needs to be changed out. The weekly clean out of this tank confirms that more fine carbon can be recovered from the current circuit by subjecting it to continuous operation.

The recovered product for the year to date is 88.1 t of material at an average of 8.81 tons per month. The average gold grade is 240 g/t which equates to 2.1 kg of gold on average contained in each batch dispatched per month. At the current gold price of R410 000/kg of gold, this monthly quantity has a value of R861 000.

According to Bailey (1987:584), the amount of fine carbon that is recoverable from the elution circuit, can be a maximum of 55% of the total plant carbon consumption. The remaining 45% fines are lost in the CIP section, to the residue out of the plant. The total consumption for 2014 was 193.6 tons of carbon. The 88.1 t recovered fine carbon by-product represented 45.5% of the total consumption. There was therefore 9.5% of product unaccounted for. The theoretical opportunity is therefore an additional 18.4 t, resulting in 1.8 t additional fine carbon recovery per month. The theoretical opportunity is R180 000 additional revenue per month. The above estimation quantifies the first advantage stipulated in **Table 4.5** below.

Table 4.5 Potential benefits for 2nd proposed implementation

Continuous filtering advantages	
1	Increased revenue
2	Reduced tank cleaning frequency
3	Increased water pump life
4	Improved water pressure due to reduced leaks at the pump seals

The change would require training for the relevant operators on shift to clean out the filter press when it is full and then place it back online. Instrumentation was installed that automatically communicates a signal to the control room when the unit is full and needs to be cleaned. A high pressure water cleaner is used for the cleaning and the entire task takes 25-30 minutes to complete.

4.2.4 Improving the “flow” of the elution batch process

The specific elution process in use was designed by Anglo American Research Laboratories (AARL) and is therefore named the AARL elution process. It is a batch process in which 5 tons of carbon is treated at a time. The objective is to reverse the equilibrium adsorption reaction in order to remove the gold from the carbon back into a high concentration solution, referred to as eluate or “pregnant solution”. The eluate is then subjected to electro-winning, where the gold precipitates onto the cathodes. The elution process takes 14 hours from start to finish, but the next process can start after 9 hours, when all the solution has been transferred. It is then pumped through the electro-winning cells for another 12 hours, resulting in total cycle time of 21 hours for the

product. In **Table 4.6** below, the steps of the two respective processes and the tank levels are illustrated for the current operation.

Table 4.6 Current critical pathway for the elution and electrowinning processes

	Time in hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Current																						
	Elution steps																					
	Electrowinning																					
	Eluate Tank Level				15	15	33	51	69	85												
	Catholyte Tank Level										85	85	85	85	85	85	85	85	85	85	85	85

The elution batch process consists of the sequential steps as illustrated in **Table 4.7** below. The desired product solution is generated in steps 2 and 4 and is collected in the eluate tank. During step 2 the level of this tank increases to 15% and during step 4 it increases to the final volume of 85%. Once the total volume is collected the “batch” is pumped across into another tank named the catholyte tank. It is from this tank that the eluate solution is circulated through electro-winning cells in which the gold precipitates onto the cathodes. This step adds another 12 hours to the time, resulting in a total of 21 hours.

Table 4.7 AARL Elution steps

Step	Name	Description	Duration
1	Pre-heat	Circulating soft water through the carbon and boiler until the temperature reaches 90^0C.	3 hours
2	Pre-treat	Pumps through a solution consisting of 4% caustic soda and 0.75% sodium cyanide solution, at 120^0C.	1.5 hour
3	Soak	Carbon soaking in the above chemical solution.	0.5 hours
4	Recycle eluate strip	Main step – consists of pumping solution from previous elution batch	4 hours

		through the column, at 120 ^{0}C.	
5	Soft water strip	Pumping soft water through the carbon into a holding tank to be used in the next elution (step 4), at 120 ^{0}C.	4 hours
6	Cool strip	Circulating ambient temperature soft water to cool the carbon prior to transfer out of the column.	1 hour

The proposed improvement is elementary, but can reduce the two succeeding processes by 4 hours overall. The recommendation is a combination of “pull” and the introduction of flow resulting in less delay. Initiate earlier pumping of solution from the eluate tank into the catholyte tank. There is no reason for the electro-winning section to wait for the eluate tank level to be 85% before pumping.

The minimum volume that needs to remain in the eluate and catholyte tanks is 5%, due to the transfer pump that starts pulling in air together with the solution at this level, which results in increased impeller wear. The eluate tank level can be interlocked with the pump in such a way that it transfers solution when the level is 15% and stops again at 5%. This action will be repeated 9 times during the steps 2-4 of the elution process. Therefore the electro-winning can commence after 5 hours when the catholyte tank receives the first 10% solution.

The potential time saving equates to 4 hours (**Table 4.8**), with upside potential. The efficiency of the electro-winning will need to be verified after the change, to validate the required time to reach the cut-off point of 10 mg/l. Due to the lower initial volumes of the catholyte tank, when the electro-winning process starts, it will pass more times through the electro-winning cells, which should increase the electro-winning precipitation rate onto the cathodes. This postulation need to be verified by means of interval sampling of the eluate, during the sequence, and be analysed by the Atomic Adsorption Spectrometry (AAS) machine.

Table 4.8 Future critical pathway for elution and electro-winning processes

	Time in hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Future																						
	Elution steps																					
	Electrowinning																					
	Eluate Tank Level				15	0	3	6	12	15	0											
	Catholyte Tank Level					15	30	45	60	75	85	85	85	85	85	85	85	85				

The opportunity is therefore the conservative minimum benefit and can increase in value with more analysis and continual improvement initiatives. The benefit of saving 4 hours on these two steps enables the plant to lower the gold inventory that is held up in the plant. The process will “pull” quicker for the next batch to be conducted, which will require more continuous movement of carbon in the CIP section, resulting in lower gold loadings. Further work on the actual implementation is required in order to quantify the exact benefits to be realised.

4.2.5 Summarised results for the qualitative study

Herewith the benefits that the plant can expect by implementing these relative simplistic changes into the current process, according to the desired future state VSM.

- The quantified benefit for improved stockpile movement is rounded to R4.000 per month. This was calculated from the time study on the loader movement. The implementation spin-off benefits are not quantified, due to the lack of actual data. The reduced stockpile size and time saving should also benefit the contractor, who could utilise the loader and trucks for transporting material to the other gold plant.
- By converting the fine carbon recovery from a batch process to a continuous one, it has the potential for increased gold production. At a current gold price of R410,000/kg it will equate to R180,000 additional revenue per month. With all resources already in place, the revenue should be mostly profit.
- The potential is a reduction of 4 hours in the elution process. With the current system, the plant can conduct 34 elution processes within a 30 day month, if done consecutively. With the proposed change, it should increase the capability

to 42 elutions per month. This equates to increased gold recovery and less gold left in the plant as inventory.

Therefore implementation of the 3 proposed improvements can contribute a net revenue of R2 200 000 per annum. Not one of these improvements requires financial funding and therefore there is no payback calculation. The current resources have spare capacity to implement these actions and immediately realise the benefit.

The challenges associated with these implementations are that not all the Lean Principles are applicable to the processing plant. The implementation of “flow” and “low inventories” are complex to quantify in financial terms. Most equipment is large and permanently installed and cannot be moved or changed to conduct parallel processing. The majority of the workforce is unskilled or semi-skilled and explaining the concepts and benefits proved to be a challenge.

4.3 Perception survey

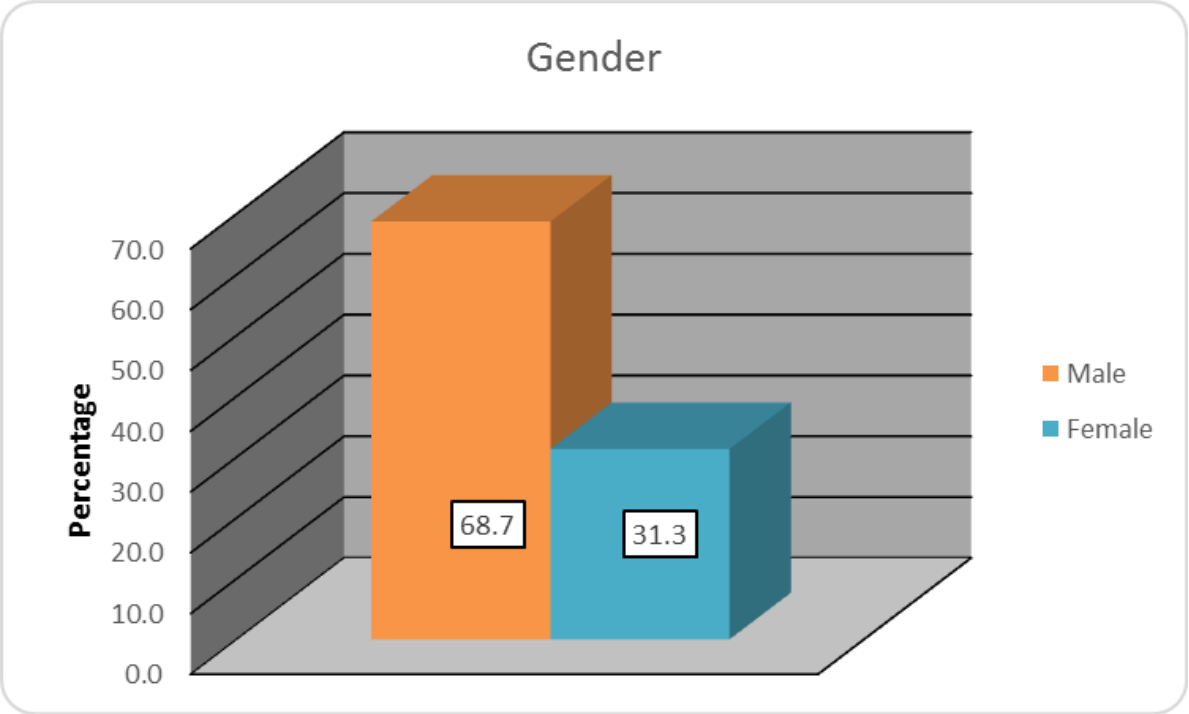
4.3.1 Introduction

With each unsuccessful implementation of a project or management initiative, the resistance to change grows. The gold processing industry is no exception, as numerous initiatives have been tried and tested over the years. The system or project may be theoretically sound, but if the people are not willing to join in on the journey, then serious consideration must be given to address resistance. The TPS model emphasises the importance of respect for employees and co-workers. The author’s recommendation is to address any such identified concerns or problems prior to Lean Manufacturing implementations, as the success relies on the implementing teams. The conducted survey measures readiness for change, as well as whether the organisational climate is stable.

4.3.2 Demographic analysis

The number of respondents was 115 in total, resulting in a 23.7% representation of the total target population. As illustrated in **Figure 4.4** below, the male respondents accounted for 69% and females for the remaining 31%. The demographic comparison is illustrated in **Table 4.9** below.

Figure 4.4 Gender



When the sample is compared to the overall plant "population", the percentage female respondents of the sample were 14% higher, as illustrated in the difference column of **Table 4.9**. This might be attributed to the fact that the females in the plant were more administratively inclined than was the case with the males, or else the females simply displayed a higher interest to participate in the survey. The responses from the white ethnic group were 25% above the plant population as demonstrated in the difference column in **Table 4.9**. Black respondents were 33% below the representation of the overall plant population.

The responses on the electronic survey yielded a higher completion percentage than the manually distributed ones. Of the 100 questionnaires distributed manually, only 50 were returned, which had a negative impact on the ethnicity representation, when compared to the population distribution.

Figure 4.5 Ethnicity

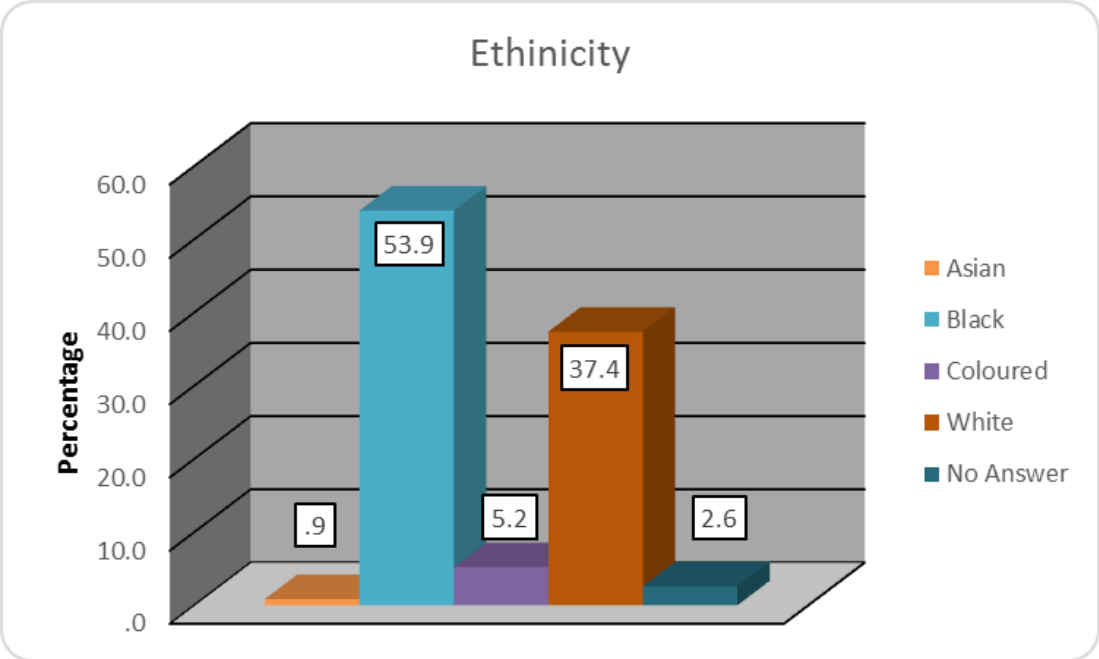
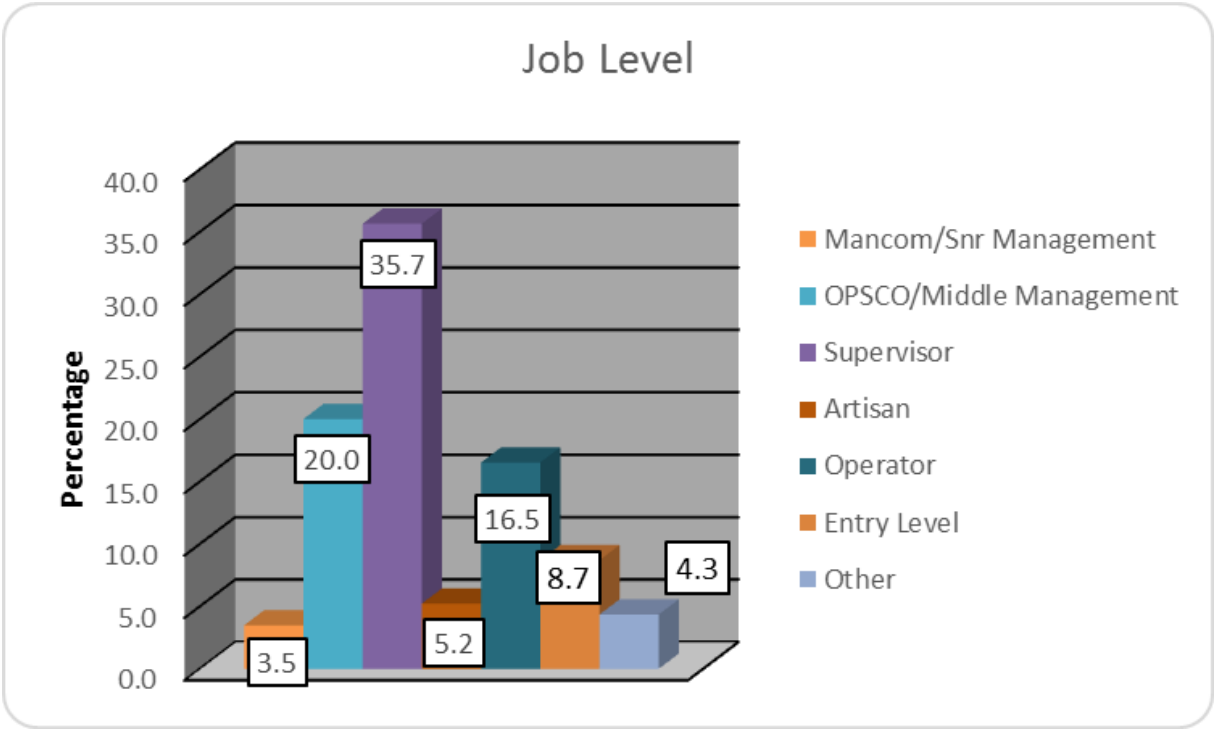


Table 4.9 Demographic comparisons between sample and population

		Population		Sample		Diff
	Category	**Frequency**	**%**	**Frequency**	**%**	
Total Employees		486	100	115	23.7%	-76.3
Gender	Male	404	83	79	69	-14
	Female	82	17	36	31	+14
Ethnicity	Black	421	87	62	54	-33
	White	58	12	43	37	+25
	Coloured	6	0.8	6	5	+4
	Indian	1	0.2	1	1	+0.8
Age Distribution	20-29	68	14	24	21	+7
	30-39	139	28.4	37	32	+3.6
	40-49	146	30	28	24	-6
	50-59	130	27	26	23	-4
	60-65	3	0.6	0	0	-0.6

Management levels represented 23.5% of the total sample, supervisors accounted for 35.7% and the general workforce (divided into artisans, operators, entry level or “unskilled” labour and other) denoted the remaining 34.8% of the total. The perception towards change management implementations were expected to be different for these specific groups, since the management is more involved with planning and initiating change, while the rest of the employees are responsible for implementation. For further analysis the groups were combined to form two clusters, consisting of management and workforce, since there were not enough participants from the original divisions to construct an ANOVA for multiple correlation statistics. A t-test was conducted and the results are discussed below.

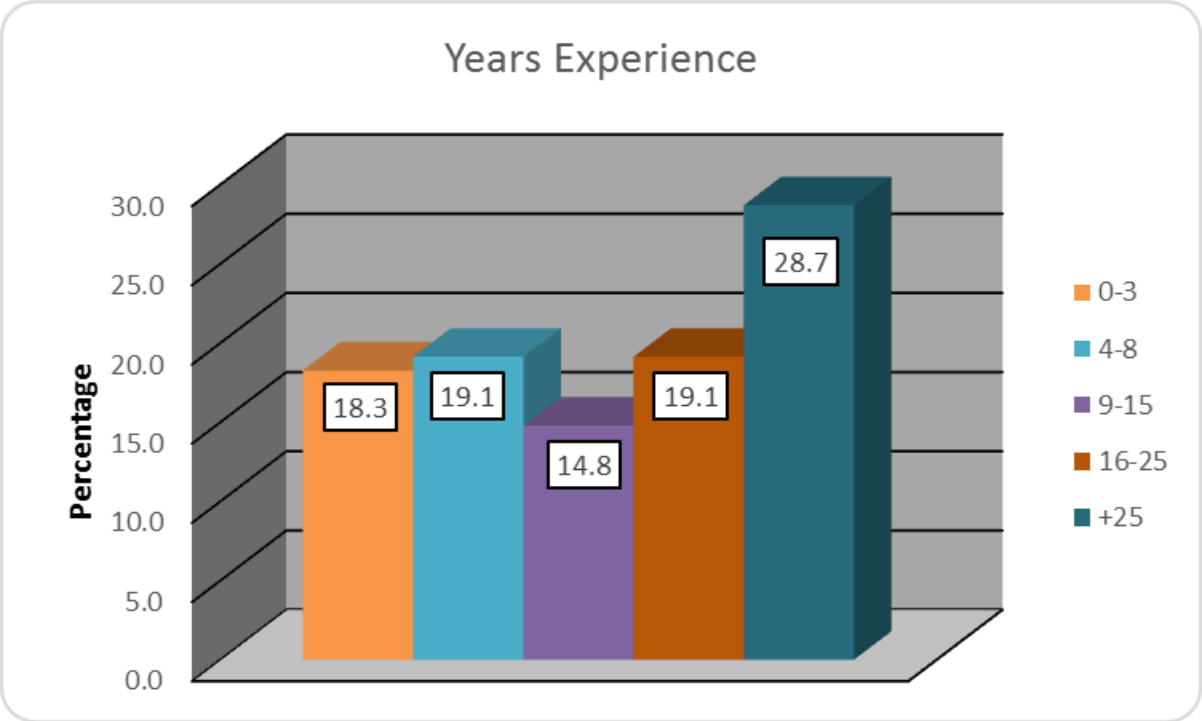
Figure 4.6 Job level



The participants of the survey were highly experienced; with a majority of 28.7% (33 out of the 115) selecting more than 25 years of experience. The remaining groups were more evenly distributed ranging from 14.1% of the employees with 9-15 years of experience to 19.1% of the employees with 4-8 and 16-25 years respectively. The concern to highlight would be that people working such long periods within one company might harbour increased resistance to change. It is important to take

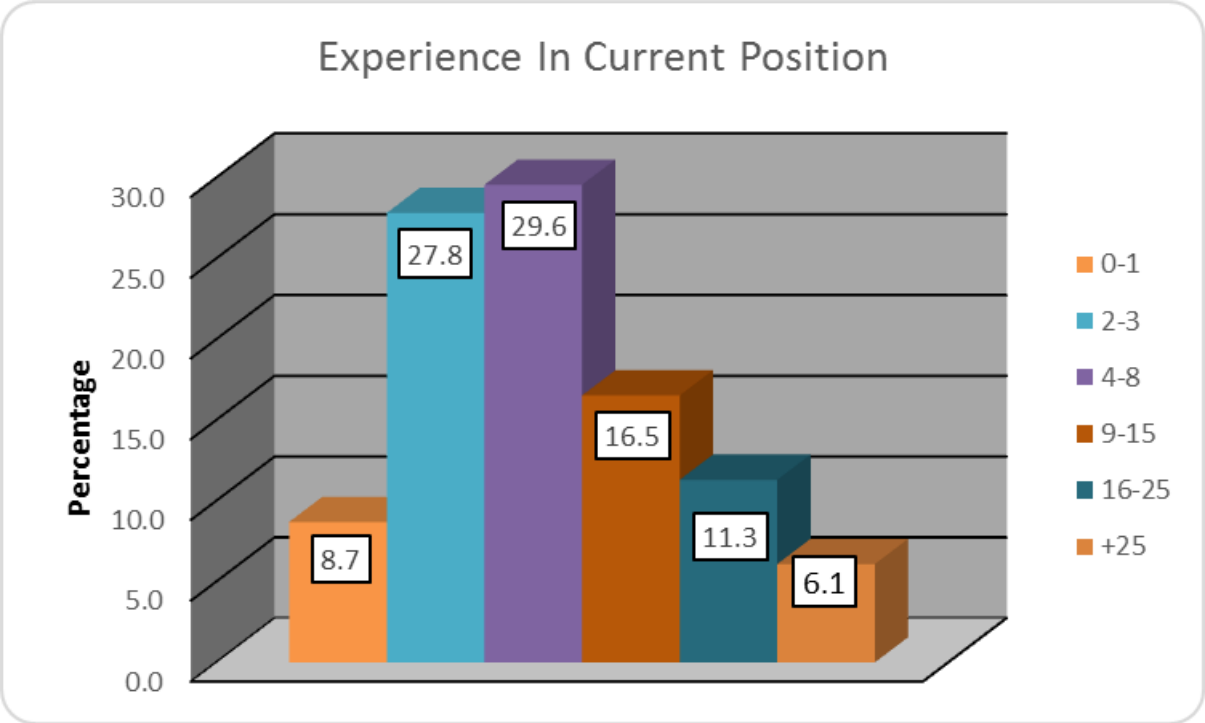
cognisance at this point of the “We tried it before, it did not work” potential obstacle to cross.

Figure 4.7 Years of experience



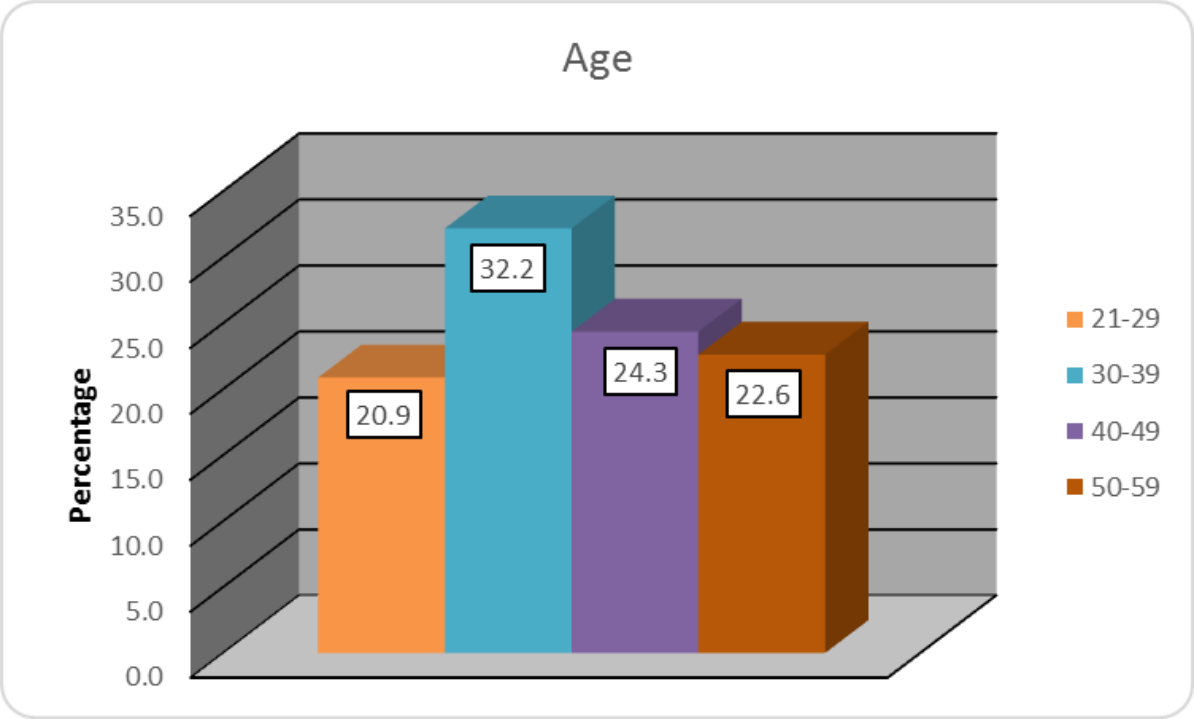
The results in **Figure 4.8** below indicate that even though employees have long service history within the company, they move between positions relative frequently when compared to years’ service. The majority of 57.4% spent between 2-8 years in their current position. Movement could be attributed to transfers, promotions or restructuring that took place within the department. These changes keep people from becoming complacent and therefore could have a positive effect on change management, since it has already been part of their company experience thus far.

Figure 4.8 Experience in current position



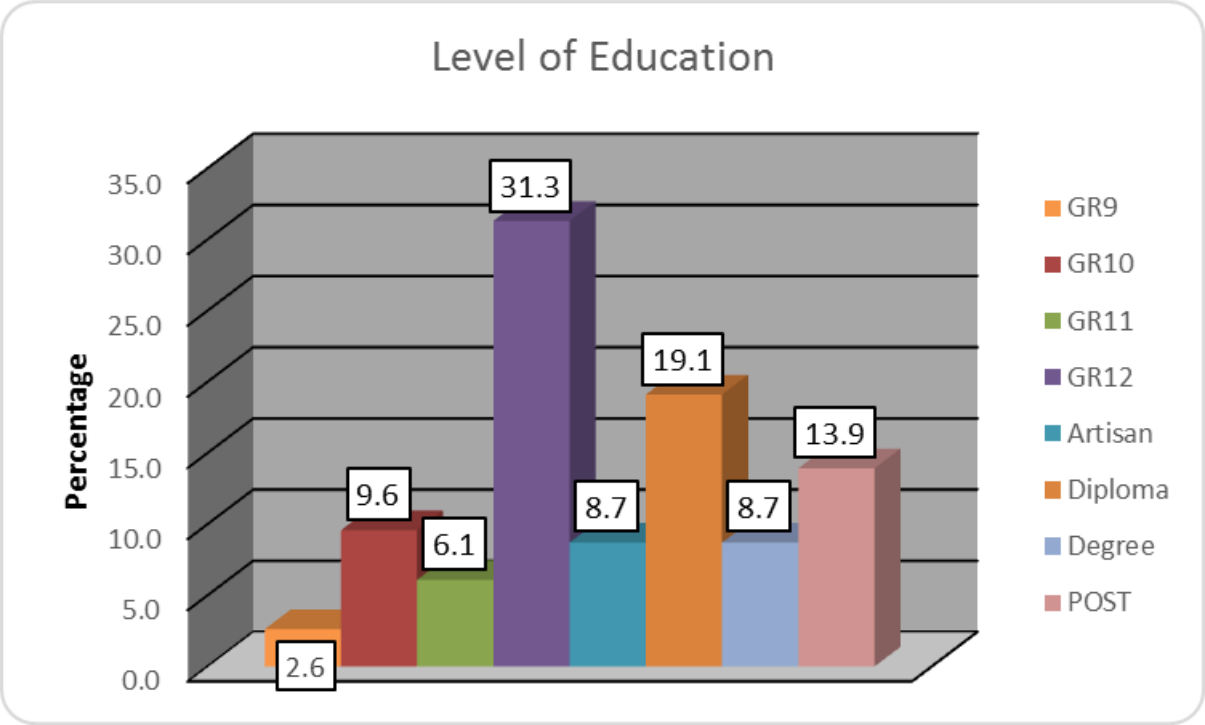
The age distribution was spread evenly between the major four age brackets of which the largest portion of the sample group was represented by 32.2%, which was those between the ages of 30 and 39. The second largest group constituted 24.3% of the total sample and represented the age group between 40 and 49 years. The 50-59 years bracket was represented by 22.6% of the participants. None of the participants exceeded the age of 59.

Figure 4.9 Age



The education or qualifications of all participants are illustrated in **Figure 4.11** below, where the number of employees without a Gr 12 qualification equates to 18.3%. This is low with regard to other mining departments, and due to the higher demand for physical "unskilled" tasks. Thus the total quantity with a school education amounts to 49.6%. The artisans, with respective trade certificates constituted 8.7% of the total. Participants with diplomas represented 19.1% of the sample, while holders of degrees and post graduate degrees constituted 8.7% and 13.9% respectively. The level of literacy contributes towards an improved understanding of the proposed changes and initiatives that the company need to undergo in order to remain competitive.

Figure 4.30 Level of education



4.3.3 Reliability analysis

The measurement used for the reliability of internal consistency was determined by calculating the respective Cronbach's alpha coefficients for each item. The first variable to be subjected to analysis was "Change Management", to which Questions 9–18 were applicable. The initial results are illustrated in **Table 4.10** below and resulted in a coefficient score of only 0.547.

Table 4.20 Change Management – Cronbach's alpha coefficient

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.547	.603	10

Upon further investigation into the individual measurements, it was observed that the inter-correlation between Question 13 and the rest, as well as Question 18 and the rest of the questions were significantly higher than for the remainder. The respective questions were analysed. Besides the inverted scoring, the construction was not clear, resulting in misinterpretation. **Table 4.11** below indicates that Cronbach's alpha

coefficient would increase if the two questions were eliminated from the results in order to obtain an improved internal consistency. These two questions were answered statistically different from the rest (**Table 4.11**). The inter-correlations highlighted this anomaly. For future work, the questions need to be rephrased to ensure a better understanding and correct interpretation.

Table 4.31 Cronbach's alpha for each question

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Q9	31.439	13.204	.380	.513	.478
Q10	31.404	12.968	.484	.550	.453
Q11	31.000	14.071	.431	.353	.483
Q12	31.175	13.916	.439	.402	.479
Q13	32.088	19.727	-.438	.309	.705
Q14	31.789	13.283	.385	.345	.478
Q15	31.877	12.392	.391	.335	.468
Q16	32.009	12.664	.394	.394	.469
Q17	31.491	13.615	.442	.341	.472
Q18	31.596	16.455	-.087	.143	.610

The questions pertaining to the change management variable consisted of eight measurement questions, of which the individual Cronbach alpha scores ranged from 0.742 to 0.769 (**Table 4.12**). These were above the criteria level stipulated for research purposes by Nunnaly (1978). The internal consistency of the measurement instrument was therefore reliable as indicated in **Table 4.13**.

Table 4.12 The Cronbach's alpha scores with removed questions

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Squared Multiple Correlation	Cronbach's Alpha if Item Deleted
Q9	24.930	15.393	.474	.488	.749
Q10	24.895	15.369	.547	.500	.737
Q11	24.491	16.659	.488	.350	.750
Q12	24.667	16.242	.541	.376	.742
Q14	25.281	15.478	.481	.325	.748
Q15	25.368	15.137	.394	.323	.769
Q16	25.500	14.978	.459	.376	.754
Q17	24.982	16.070	.510	.336	.745

Table 4.13 Cronbach's alpha coefficient for both variables

	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
Change Management	.773	.787	8
Organisational Climate	.759	.760	11

4.3.4 Frequency analysis

The first portion of the questionnaire was aimed at the change management variable and it measured the employee perception of current practice and self-participation. Questions 9–18 were centred round the individual's own contribution in driving the need for change. The overall score for these four questions were on average in agreement with a standard deviation below 1, signifying a close concentration of values around the mean. There was a catch in Question 13 for supervisors and management, to make them realise that employees must be engaged as part of the change management process from the start. The scoring was inversed and catered for in **Table 4.14**, but from the negative inter-correlations measured in the reliability, it reflected a potential misunderstanding of the question's intent.

Table 4.14 Questionnaire scoring for change management

	Change Management	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree	Total	Mean	Standard Deviation
Q9	I make comments in meetings on new ways of doing things?	5	11	14	73	12	115	3.66	0.94
Q10	I signal the value of change and improvement with positive statements?	4	8	17	75	10	114	3.69	0.86
Q11	I encourage people to express ideas and opinions even it they differ from my own?	1	3	6	79	26	115	4.10	0.67
Q12	I see my "task" as inspiring others towards improvement in their jobs?	0	6	15	76	18	115	3.92	0.70
Q13	When changes are made in the department, I plan the entire change and then announce it to employees?	9	31	32	37	6	115	3.00	1.06
Q14	I am able to get higher level managers to support ideas for improvement?	5	15	41	48	6	115	3.30	0.92
Q15	People feel free to talk to management about problems in their jobs?	8	26	27	42	12	115	3.21	1.12
Q16	Confidence and trust is generally shown by management towards their employees?	12	20	33	47	3	115	3.08	1.05
Q17	I offer suggestions for change to employees at the operational level?	1	12	23	73	5	114	3.61	0.77
Q18	I am NOT comfortable being told by my management that a better way is needed for a task in my department?	15	54	22	23	1	115	3.51	0.98

The mean value reduced to 3.00 and the standard deviation increased to 1.06. Questions 14–17 focussed on the perceptions pertaining to managers and change management. The mean decreased and the standard deviations increased, signifying that the current management of change could be improved. Levels of mutual trust and management support were perceived as less optimistic. The mean values were marginally above the 3.00 level and standard deviations above 1, indicating the wider spread of answers. Question 18 was another inverse attempt but its score in the reliability test indicated the inter-correlation to be negative. The question was vague and excluded for reliability purposes.

Table 4.15 Questionnaire scoring for organisational climate

	Organisational Climate	Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree	Total	Mean	Standard Deviation
Q19	Employees ideas are encouraged and used constructively by management?	5	18	41	49	2	115	3.22	0.88
Q20	Management need to apply fear and threats to get employees to conduct their work?	25	43	27	18	2	115	3.62	1.04
Q21	Employees receive encouragement and sometime material rewards to do their work well?	19	24	27	41	4	115	2.89	1.16
Q22	All employees feel a strong sense of responsibility here for achieving organisational goals?	10	22	35	46	2	115	3.07	1.00
Q23	A strong sense of coorporative teamwork exist in this coorporation?	11	19	35	48	2	115	3.10	1.01
Q24	There is poor upwards communication in this company?	4	24	39	40	8	115	2.79	0.96
Q25	Employees usually accept communications from management trustingly?	3	18	41	52	1	115	3.26	0.82
Q26	Management are generally unaware of the problems faced by employees?	3	36	31	38	6	114	2.96	1.02
Q27	Resistance to company policies from the workforce is common?	6	40	33	33	3	115	3.11	0.97
Q28	Responsibility is widely delegated among employees in this organisation?	5	10	38	61	1	115	3.37	0.83
Q29	Formal control by management is undermined by external factors?	4	31	44	30	4	113	3.06	0.98

4.3.5 Descriptive statistics, T-tests and ANOVA

The T-test determines if the difference between two means are statistically significant (Cloete, 2011). The T-tests were conducted for the following groups: gender, ethnicity and job level. The multiple segments underneath ethnicity and job level were combined into two main clusters for each group. For ethnicity, the main groups were black and white and constituted 91.3% of the total population. For job level, the Mancom and Opsco groups were combined to form the management cluster, while the rest of the remaining segments were combined to form the worker group.

4.3.5.1 Gender T-test

The first analysis was conducted on the gender groups. **Table 4.16** below contains the summary of the results.

Table 4.16 T-test for gender groups

		N	Mean	Std. Deviation	P-Value	Effect Size
ChangeManagement	Male	79	3.6329	.58915	.071	
	Female	36	3.4317	.44988	**.047**	**0.34**
OrgClimate	Male	79	3.1128	.55359	.583	
	Female	36	3.1717	.48094	.563	0.11

The p-value of 0.047 for the change management factor (Questions 9-18) indicated that there was a statistically significant difference in the way that the female group answered the questionnaire. The effect size of 0.34 indicated that the practical significance of this difference was medium. There was no statistically significant difference in the way that the two genders answered the questions, relating to the organisational climate.

4.3.5.2 Ethnicity T-test

The mean values tested similar, and positive, for both the black and white groups, with regard to the change management factor. The white group scored more negative on organisational climate than the black group. No significant statistical difference in the way that these groups answered the questions, relating to change management or organisational climate. The effect size for organisational climate at 0.3 indicated a medium practical significant difference in the way the groups responded to the second factor. The summary of results is illustrated in **Table 4.17** below.

Table 4.17 T-test for ethnicity

		N	Mean	Std. Deviation	P-Value	Effect Size
ChangeManagement	Black	62	3.5551	.60035	.980	
	White	43	3.5523	.45171	.978	0.00
OrgClimate	Black	62	3.1789	.44566	.070	
	White	43	2.9852	.63758	.090	0.30

4.3.5.3 Job level T-test

The T-test conducted on the job level groups of management and workers yielded similar mean values across both factors. The mean of the measurement for change management was more positive than for organisational climate. From the measured p-values and effect sizes in **Table 4.18** below, it could be deduced that there was no statistically significant difference, nor practical significant difference, in the way that management groups answered the questionnaire, relative to the worker groups.

Table 4.18 T-test for job level

		N	Mean	Std. Deviation	P-value	Effect Size
ChangeManagement	Management	68	3.7813	.44925	.225	
	Worker	40	3.8370	.35242	.073	0.12
OrgClimate	Management	68	3.1083	.59214	.779	
	Worker	40	3.1386	.44153	.763	0.05

4.3.5.4 ANOVA test for employee age

The different age brackets did not yield significant statistical differences in the way they answered questions for both factors. In **Table 4.19** below, the summarised results indicated that the effect sizes for change management were below the cut-off points, but there were medium effects of practical significance between the brackets of 20-29 and 30-39 years, and also for 20-29 and 50-59 years. The effect sizes were 0.31 and 0.36 respectively.

Table 4.19 ANOVA for employee age

		N	Mean	Std. Deviation	P-Value	Effect_Size		
						[20-29]&	[30-39]&	[40-49]&
ChangeManagement	20-29	24	3.4948	.59376				
	30-39	37	3.5755	.54670		0.14		
	40-49	28	3.6518	.43482		0.26	0.14	
	50-59	26	3.5433	.65854		0.07	0.05	0.16
	Total	115	3.5699	.55534	.779			
OrgClimate	20-29	24	3.2424	.44022				
	30-39	37	3.0958	.47186		**0.31**		
	40-49	28	3.1494	.68488		0.14	0.08	
	50-59	26	3.0594	.50840		**0.36**	0.07	0.13
	Total	115	3.1312	.53052	.636			

Across all the age brackets the mean scores indicated positive answers for the change management factor and, ranged from 3.49 to 3.65. For the organisational climate the mean scores were lower, with a range from 3.06 to 3.24 between the different age brackets.

The last ANOVA test was conducted for the brackets established for years' experience within the company. There was a significant statistical difference in the way that the participating groups answered the questions within the organisational portion of the questionnaire. The p-value of 0.005 was by the power of ten less than the cut-off point of 0.05. The summarised data is illustrated in **Table 4.20** below, and indicated that there were numerous measured effect sizes, for both factors, that indicated practical

significant differences between the respective groups. The medium effect sizes, for the change management factor all occurred between the most inexperienced group, employed only 0-3 years at the company, and the more experience brackets of 4-8 years, 9-15 years and 16-25 years. The effect sizes indicated medium practical significant differences, with values of 0.3, 0.43 and 0.44 respectively. Thus different generations responded differently to the change management section.

Table 4.20 ANOVA for years of experience

		N	Mean	Std. Deviation	P-Value	Effect_Size [0-3]&	[4-8]&	[9-15]&	[16-25]&
ChangeManagement	0-3	21	3.4246	.50426					
	4-8	22	3.5909	.56324		**0.30**			
	9-15	17	3.6765	.59137		**0.43**	0.14		
	16-25	22	3.6477	.49346		**0.44**	0.10	0.05	
	+25	33	3.5417	.60971		0.19	0.08	0.22	0.17
	Total	115	3.5699	.55534	.632				
OrgClimate	0-3	21	3.2987	.28769					
	4-8	22	3.0868	.50224		**0.42**			
	9-15	17	2.9412	.68177		**0.52**	0.21		
	16-25	22	3.4174	.41675		0.28	**0.66**	**0.70**	
	+25	33	2.9614	.56042		**0.60**	0.22	0.03	**0.81**
	Total	115	3.1312	.53052	**.005**				

Within the organisational climate factor, the effect sizes were medium to large. Between the 0-3 years of experience bracket and 4-8 years, there were medium practical significant differences with an effect size of 0.42. The inexperienced group, namely 0-3 years, recorded large effect sizes, while the 9-15 years and +25 years brackets, logged 0.52 and 0.60 respectively. The most experienced brackets of 16-25 years of experience and +25 years had the highest effect size scores, when compared with the other brackets. The practical significant differences between the 16-25 years of experience bracket, with 4-8 years and 9-15 years, measured high at 0.66 and 0.70 respectively. Lastly, the effect size for the +25 years of experience bracket, compared with the 16-25 years bracket, was the largest at 0.81. This inferred that there was a large visible difference in the way these groups answered the questions for the second factor.

4.3.6 Summarised results for the quantitative study

The calculated Cronbach's coefficients were 0.773 and 0.759, after two questions were removed. This measurement of internal consistency was above the acceptable limits for research purposes (Nunnaly, 1978). The descriptive statistics illustrated that females answered the questions on change management, statistically and significantly different than males. The effect size though, only ascribes a medium practical significance to this difference.

For job level there was no statistical or practical significant difference noted between the ways in which the management and the workers answered their questions. All the calculated values were within the limits, which indicated a low threat-risk towards change implementation where dynamic groups are involved.

The group for different ages did not yield any statistically significant differences in the way they answered the questionnaire. Two medium strength effect sizes were noted, but not considered to be a significant risk.

Lastly, the experienced groups did result in statistical and practical differences for the organisational climate aspect. The p-value of 0.005 was the lowest of all measures, indicating a significant difference between the answers from these groups. It was noted that the effect sizes increased as the years of experience increased, ranging 0.42 to 0.81.

4.4 Conclusion

1. Quantitative study

The identified improvement projects could derive further value from the current process without acquiring additional financial resources. The combined annual benefit was calculated at R2.2 million and could be realised immediately after implementation. The three suggested projects were:

- Improved stockpile management by introducing material pull – R48,000/annum;
- Implement flow in the fine carbon recovery circuit – R2.16 million/annum; and
- Implement flow in the elution section – not quantified.

The failure to quantify the third improvement project stems from the difficulty to convert saved time into a financial value. The reduced time should result in lower gold inventory in the plant, but varies according to the associated variables involved. The noted improvement is therefore an estimated 4 hours reduction in the time taken for the elution and electro-winning processes. After the modification, the plant would be able to conduct 42 elutions over a 30 day month, instead of the current capacity of only 34.

The identified challenge for project implementations, pertaining to the actual processes, was for the unskilled people in the plant to comprehend the Lean Concepts. To match the concept to the process flow would consume time and skills.

2. Qualitative study

The statistical analyses of the survey indicated no substantial risk to prevent Lean Manufacturing implementation. The respective groups that were analysed consisted of gender, ethnicity, job level, age and years of experience in the company.

Considering the social aspects as well as the history associated with South African mining, the measures for ethnicity and job level were considered most important in terms of the sensitivity towards change and climate. The results for ethnicity were positive with only a medium effect size recorded for the white group on organisational climate, but with a p-value of 0.09, there was no statistical significant effect noted.

For the respective gender and age groups, the recorded statistical and practical significance was of lower concern and not perceived as a threat to implementing changes on the plant. There was a statistically significant difference in the way in which the different experience groups answered the questionnaire. The p-value of 0.005 for the organisational climate factor, inferred the significance of the difference. The experience brackets of 9-15 years of experience and +25 years scored an average of 2.94 and 2.96 respectively, indicating less positive sentiments towards the organisational climate than the rest. Effect sizes ranged from a medium practical significance of 0.41 to a high practical significance of 0.81.

The highly experienced employees', with +9 years of experience, scores reflected readiness for change, but depicted the organisational climate to be less conducive, relative to the other groups. It reflected the uncertainty that highly experienced employees live within the current mining climate. These two groups would have experienced the decline in productivity since 2001.

4.5 Recommendations

Based on the derived benefits associated with the project implementations, it was clearly imperative that the plant commences with implementation. The author's recommendation is to task the metallurgist to draft the final project scope and oversee the implementation. Recommendations for each project include:

Engage the current contractor who is responsible for the loading and hauling of material, in order to discuss the change implementation. It will entail the drafting of a new proposal and an amended clause to the current contract, with regard to the new reduced stockpile volumes required on the stockpile. Once this stage has been completed, it needs to be approved by the process manager in order to commence with implementation.

Arrange a consultation session with the production employees in order to discuss the additional requirements of the fine carbon section. Highlight the potential benefits in order to obtain buy-in from the different groups. Once this has been achieved, the respective groups need to attend a training session to ensure that everyone is competent for the task at hand.

Approach the instrumentation department and explain the benefits of a lower gold inventory. Even though it is not quantified in exact numbers, it should be possible to establish a figure after the fact, when enough data has been compiled for proper statistical comparisons. The change can be completed by changing the process control software. After the logic programming, the sampling practice will need to be revised, since a single sample will not be representative anymore.

Revisit the future VSM at a determined future date after the projects are implemented and sustainable benefits are realised. At that stage the future VSM will become the

current VSM, and repeat the exercise with a different group to create a new future VSM with additional improvement projects for implementation.

The interpretation of the data obtained from the survey was that there was no prominent factor that could derail the implementation of Lean Manufacturing principles within the processing plant. Although the most experienced group noted statistical and practical differences in the way the survey was done, the scores still reflected an average score above the median of 2.5.

The internal consistency of the questionnaire was determined by using Cronbach's alpha coefficients. The coefficients tested well above the acceptable limits at 0.773 and 0.759 for both the change management and organisational climate factors being measured.

The T-tests performed on the gender group raised one statistically significant difference in the way that females answered the questions regarding the change management factor, with the p-value being 0.047. The accompanying effect sizes confirmed a medium practical significant difference for the same measurement. The female participants' percentage was higher than what the actual population consisted of. In the processing plant females were not represented in front line production and supervision positions. This might have influenced the way in which the females in the group's answers differed from the way in which the participating males in the group answered questions.

No statistically significant differences were noted in the ethnic group consisting of mainly white and black participants. A practically significant medium difference was noted in the way in which the white respondents answered the organisational climate questions.

No statistically significant differences were noted for the job level group, which consisted of a combined group for management and another one for workers. The anticipation was that out of all the groups tested, some differences would most likely be noted in this specific group. Especially since management is viewed as the "change management initiators" and custodians of the process, while the workers are the

implementers responsible for the success thereof. The result to the contrary indicated that these groups answered the questionnaire in a statistically similar ways.

The two ANOVA tests were conducted for the multiple brackets used to categorise age and work experience. There were no significant statistical differences noted for the way that the different age groups completed the questionnaire. Two effect sizes had medium practical differences, noted at 0.31 and 0.36 for the age bracket 20-29 years of experience, as well as the brackets for 30-39 years and 50-59 years.

There was a statistical significant difference in the way in which the different experience groups answered the questionnaire. The p-value of 0.005, for the organisational climate factor, proved the significant difference in the way that the respective groups answered this segment. The experience brackets of 9-15 years of experience and +25 years scored an average of 2.94 and 2.96 respectively, which was lower than the rest, but still above the mean of 2.5. Effect sizes ranged from a medium practical significance of 0.41 to a high practical significance of 0.81. This result might need further research to explore the root cause for the noted differences but it alone is not deemed a serious risk to implementation of the initiatives.

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Appendix 1 Toyota 14 principles

The 14 principles of the Toyota Way (Liker, 2004:37)

1.	Base decisions on long term philosophy, even at the expense of short term financial goals.
2.	Create continuous process flow to bring problems to the surface
3.	Use “pull” systems to avoid over production
4.	Level out the workload
5.	Build culture of stopping to fix problems, to get quality right the first time
6.	Standardised tasks are the foundation for continuous improvement and employee empowerment
7.	Use visual control so no problems are hidden
8.	Use only reliable, thoroughly tested technology that serves your people and processes
9.	Grow leaders who thoroughly understand the work, live the philosophy, and teach it to other.
10.	Develop exceptional people and teams who follow your company’s philosophy
11.	Respect your extended network of partners and suppliers by challenging them and helping them improve.
12.	Go and see for yourself to thoroughly understand the situation.
13.	Make decisions slowly by consensus, thoroughly considering all options, implement decisions rapidly.
14.	Become a learning organisation through relentless reflection and continuous improvement.

Appendix 2 Technical process parameters

Section 1 - 4 Ore Storage and Transport

Table 25 Section 1-4 technical process parameters

Production	Mine delivers 4500 t ore per day Process 1200t per day of waste rock dump material Plant can process 5700t per day
Ore Flow	Up to 600 tons per hour from mine Up to 300 tons per hour form waste rock dump Up to 350 tons per hour from storage silo into plant
Grades	Varies from 0.5g Au/t, for waste rock dump ore ~8-10g Au/t for the reef bearing ore
Conveyor belts	6 x conveyor belts 1200mm wide 9 transfer points
Storage	First storage capacity is 1500 t Second storage capacity is 3500 t x 3 Waste rock stockpile 40,000t target

Section 5 – Milling

Section 5 technical process parameters

Production	3 ROM SAG mills 9.2m x 4.85m Capability – 85t/hr Installed Power - 3000KW
Steel Balls	9% by volume

	100mm diameter 750g/t consumption
Conveyor belts	3 x conveyor belts feeding mills 1200mm wide
Hydrocyclones classification	85% passing 0.075mm 150% recirculating load

Sections 6-12 Treatment

Section 6 -12 technical process parameters

Thickeners	3 x 45m diameter thickeners Product relative density – 1.55 Flocculant addition 25g/t
Leach	10 tanks of 1000m^3 volume Compressed air addition Mechanical agitation Sodium Cyanide addition of 250g/t
CIP	8 tanks of 212m^3 volume Carbon concentration 15g/l
Elution	3 x AARL circuit 120^{0}C 2% Caustic Soda 1% Sodium Cyanide
Electrowinning	15 cells Applied Potential – 3V DC Applied Current – 600A
Residue	2 x tanks 1200m^3 volume Mechanically agitated
TSF	Slurry pumped 6km

Section 13 Recovery

Section 13 Recovery technical process parameters

Electrowinning	15 cells Applied Potential – 3V DC Applied Current – 600A
Furnaces	1 x Arc furnace 1 x Induction furnace

Appendix 3 Questionnaire

Change Management and Climate

Demographics

The completion of this questionnaire is completely voluntary.
The results will be used in a study for a degree with NWU and is NOT company related.

Please note that the answers to these questions will be kept confidential.
Forms and records will be removed after completion of the study.
Do Not identify yourself. No name or company number is required.
There are no right or wrong answers so please indicate your true opinion.
Mark a response over the box that best represent your view.
The answers will be loaded and only the data will be available for statistical analyses

1. Are you male or female?

- Male
- Female

2. What is your ethnicity? (Please select all that apply.)

- Asian
- Black
- Coloured
- White / Caucasian
- Prefer not to answer
- Other (please specify)

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Change Management and Climate

3. How many years experience do you have in the organisation?

- 0-3
- 4-8
- 9-15
- 16-25
- 25+

4. Which of the following best describes your current job level?

- MANCOM / Senior Management
- OPSCO / Middle Management
- Supervisor
- Artisan
- Operator
- Entry Level
- Other (please specify)

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Change Management and Climate

5. Years experience in current position?

- 0-1
- 2-3
- 4-6
- 9-15
- 16-25
- 25+

6. Which category below includes your age?

- 17 or younger
- 18-20
- 21-29
- 30-39
- 40-49
- 50-59
- 60 or older

Change Management and Climate

Section B

7. Does the organisation have a clear mission statement defining its basic purpose?

- Yes
- No
- Don't know

8. What is the highest level of education you have completed?

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Change Management and Climate

Change Management and Climate Survey

Please mark an answer box below each question

9. I make comments at meetings on new ways of doing things.

Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
○	○	○	○	○

10. I signal the value of change and improvement with positive statements

Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
○	○	○	○	○

11. I encourage people to express ideas and opinions even if they differ from my own?

Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
○	○	○	○	○

12. I see my "task" as inspiring others towards improvement in their jobs?

Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
○	○	○	○	○

13. When changes are made in the department, i plan the entire change and then announce it to employees?

Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
○	○	○	○	○

Change Management and Climate

14. I am able to get higher level managers to support ideas for improvement?

Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
○	○	○	○	○

15. People feel free to talk to management about problems in their jobs

Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
○	○	○	○	○

16. Confidence and trust is generally shown by management towards their employees

Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
○	○	○	○	○

17. I offer suggestions for change to employees at the operational level

Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
○	○	○	○	○

18. I am NOT comfortable being told by my management that a better way is needed for a task in my department.

Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
○	○	○	○	○

Change Management and Climate

19. Employee ideas are encouraged and used constructively by management

Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
○	○	○	○	○

20. Management need to apply fear and threats to get employees to conduct their work

Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
○	○	○	○	○

21. Employees receive encouragement and sometime material rewards to do their work well

Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
○	○	○	○	○

22. All employees feel a strong sense of responsibility here for achieving organisational goals

Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
○	○	○	○	○

23. A strong sense of cooperative teamwork exist in this coorporation

Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
○	○	○	○	○

Change Management and Climate

24. There is poor upward communication in this company

Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
○	○	○	○	○

25. Employees usually accept communications from management trustingly

Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
○	○	○	○	○

26. Management are generally unaware of the problems faced by employees

Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
○	○	○	○	○

27. Resistance to company policies from the workforce is common

Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
○	○	○	○	○

28. Responsibility is widely delegated among employees in this organisation

Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
○	○	○	○	○

Change Management and Climate

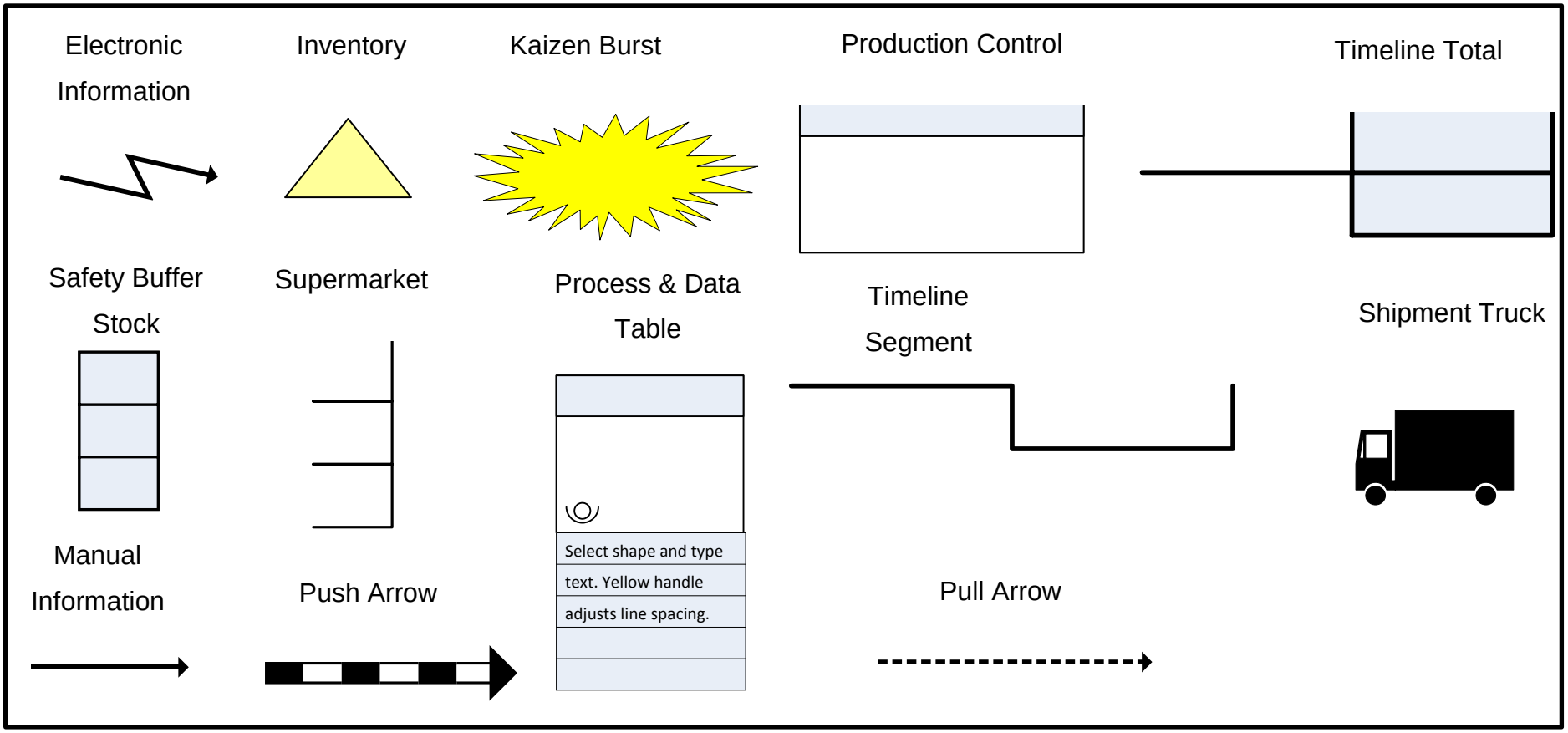
29. Formal control by management is undermined by external factors

Strongly Disagree	Disagree	Neither Disagree Nor Agree	Agree	Strongly Agree
○	○	○	○	○

Thank You for participating in this research questionnaire.

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Appendix 4 Value Stream Map (VSM) Flowchart Icons



Appendix 5 Stockpile Management Improvement

1. Stockpile position ***close to*** loading bin – Loading takt time





2. Stockpile position ***far*** from loading bin – Loading takt time

