University of Pretoria

The Development of a Continuous Improvement Modelfor a South African Minerals Beneficiation Plant

by

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Submitted in partial fulfilment of the degree

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Project Report Summary

The Development of a Continuous Improvement model for a South African Minerals Beneficiation Plant

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South Africa is blessed with a plethora of mineral resources, and as such several mineral beneficiation plants are in operation. In the mining value chain, a processing facility is seen as the bottleneck. The reason for this is quite simple. Large quantities of ore are removed in a highly industrialised process from mining activities. This large amount of ore needs to be beneficiated through capacity constrained processing facilities. In order to maintain an economically viable balance between life of mine, and maximum throughput, a large portion of ore extracted from South Africa is exported to foreign countries. The ore is then further beneficiated in plants that do not necessarily suffer from the same constraints as the South African plants. These constraints include labour costs, electricity availability and pricing, water usage etc.

Even though the downstream beneficiation of minerals will have a profound effect on the South African economy, it is of utmost importance that the Mineral Beneficiation Plants (MBP's) responsible for a large portion of the beneficiation strategy, be operated effectively to allow local end users of their products to remain internationally competitive.

It is clear that MBP's play an integral part in the value chain of the minerals industry, and effective operation of these plants are critical. It is of utmost importance to ensure that MBP's are operating at full capacity, as effectively as possible, and within budget constraints.

In order to achieve this objective, MBP's need to implement a sustainable Continuous Improvement Programme. Several models are available and have been utilised with variable success rates in some MBP's around the world, however none of these models specifically address CI from a minerals processing point of view.
This study aims to develop a model which can be exclusively used for CI in South African MBP's. A survey was conducted to understand the requirements that a CI model should fulfil. The survey was completed by respondents in both junior and senior roles within different resourcing and consulting organisations as well as academic institutions.

It was found that most respondents prefer a model which involves an amalgamation of current CI models i.e. six sigma, theory of constraints and lean manufacturing. A new model was developed using the elements from these existing models that are applicable to MBP's. The model also incorporates strategic direction required to implement it successfully. It focusses on the core elements that would result in process improvement. These are as follows:

- Reduction in Waste
- Improvement in Quality
- Improvement in Efficiency
- Decrease in cost

A case study is shown which highlights the applicability and success of the model within a South African Ferro Alloy plant.

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List of Abbreviations

4M	:	Man, Machine, Method, Material
5S	:	Sort, Set, Shine, Standardise, Sustain
BPM	:	Business Process Management
CI	:	Continuous Improvement
CPM	:	Critical Path Method
CTQ	:	Critical to Quality
DMAIC	:	Define, Measure, Analyse, Improve, Control
EMV	:	Expected Monetary Values
HIM	:	Hexagonal Improvement Model
IGS	:	Idea Generation Session
ISO	:	International Organisation for standardization
JSE	:	Johannesburg Stock Exchange
KPI	:	Key Performance Indicator
KVD	:	Key Value Driver
LM	:	Lean Manufacturing
MBP	:	Mineral Beneficiation Plant
PDCA	:	Plan, Do, Check, Act
PERT	:	Programme Evaluation Review Technique
QECW	:	Quality, Efficiency, Cost, Waste
R&D	:	Research and Development
SAF	:	Submerged Arc Furnace
SHE	:	Safety, Health, Environment
SS	:	Six Sigma
TOC	:	Theory of Constraints
TPM	:	Total Productive Maintenance
TQM	:	Total Quality Management

Chapter 1

"God sleeps in the minerals, awaken in plants, walks in animals, and thinks in man"
Arthur Young

1.1 Introduction and Background

1.1.1 Introduction

The role of Mining and Minerals Beneficiation in the South African Economy

South Africa is one of the world leaders in mining and minerals processing. In fact, mining accounted for 8.8 % of the Gross Domestic Product in 2011, with employment levels above 500 000. By the end of 2011, the mining sector accounted for 29 % of the value of the Johannesburg Stock Exchange (JSE). Total primary minerals sales exports were R 282 billion in 2011, which accounted for 38 % of South Africa's total merchandise export (South African Chamber of Mines, 2011).

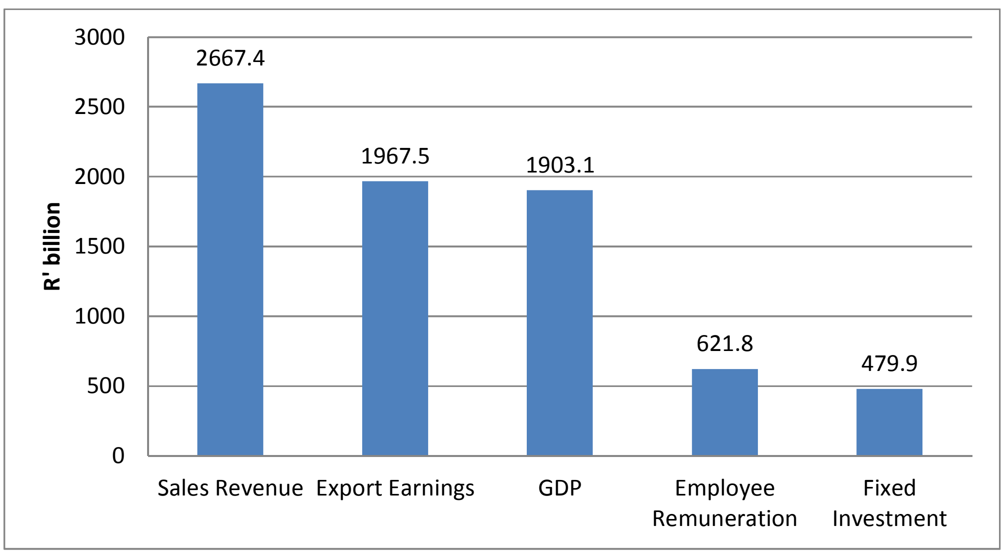


Figure 1 - The contribution of mining to SA over the past decade expressed in 2011 real rand terms (South African Chamber of Mines)

It is with this knowledge, that the South African Government developed a Minerals Beneficiation Strategy.

Beneficiation of minerals downstream of the value chain, will ensure that ore is turned into high value intermediate and finished products that will lend leverage to long term benefits from the country's substantial mineral wealth (Cramer,2010).

Table 1 – Role of South Africa in world mineral supply base*

Commodity	Unit	Reserve Base	World Rank
Gold	t	6000	1
PGM's	t	70000	1
Diamonds		N/A	4
Iron-Ore	Mt	1500	13
Chromium	Mt	5500	1
Manganese	Mt	4000	1
Vanadium	Mt	12	2
Nickel	kt	3700	8
Titanium	Mt	71	2
Coal	Mt	30408	6
Uranium	kt	435	4

***Source – South African Chamber of Mines (Adapted)**

Table 1 shows the role of South Africa in the world mineral supply base. It focuses on the ten commodities identified for further mineral beneficiation as highlighted by the Minister of Mineral Resources, Mrs Susan Shabangu in the Minerals Beneficiation Strategy of Government.

Even though the downstream beneficiation of minerals will have a profound effect on the South African economy, it is of utmost importance that the Mineral Beneficiation Plants (MBP's) responsible for a large portion of the beneficiation strategy, be operated effectively to allow local end users of their products to remain internationally competitive.

It is clear that MBP's play an integral part in the value chain of the minerals industry, and effective operation of these plants are critical. It is of utmost importance to ensure that MBP's are operating at full capacity, as effectively as possible, and within budget constraints.

In order to remain competitive, it is essential that MBP's in South Africa adopt a new way of doing business, which involves continuously improving the process and focussing attention on innovation and problem solving. This proposed research project will focus on the development of such a continuous improvement (CI) model.

Although many CI techniques exist in literature, very few have its roots in a continuous process plant, with most CI research conducted on batch and assembly-type plants. Existing CI techniques will be considered, but the emphasis will be placed on the application of these and/or newly developed techniques in a process environment.

1.2 Rationale of the research

In a global competitive market, an organisation has to continuously improve and be able to alter and adapt to changing economic conditions. The recent recession has proved that organisations with efficient and effective management principles can weather the storm of economic turmoil. It is imperative in these times that organisations, including mining companies and its business units, have an efficient Business Process Management Programme in place.

Business Process Management (BPM) is defined by Zairi (1997:64) as a structured approach to analyse and continually improve fundamental activities such as manufacturing, marketing, communications and other major elements of a company's operation. It is important to note that BPM is based on a continuous approach of optimisation through problem solving and reaping out extra benefits (Zairi 1997:65). This continuous approach of optimisation can be seen as continuous improvement of a given parameter. In this study, focus will be on the creation of acontinuousimprovement model that can be used equally well in any MBP.

The problem faced by MBP's today is that the majority of CI techniques strive to improve quality and in some cases throughput. These techniques, such as Lean Manufacturing (LM), Theory of Constraints (TOC) and Six Sigma (SS) mostly address CI issues found in batch and assembly type plants.

MBP's such as smelters, concentrators and refineries run continuous processes with stoppages mainly limited to maintenance. It is found that the abovementioned techniques are used in MBP's, however the application thereof does not seem natural, with force fitting at the order of the day.

The research aims to develop a new continuous improvement model that could successfully be applied to any MBP.It must be noted that improvement initiatives will only succeed if it is part of an improvement strategy. Strategic objectives have to be translated into improvement programs (Carpinetti& Martins 2001:283). Figure 2 shows a framework for strategy related continuous improvement.

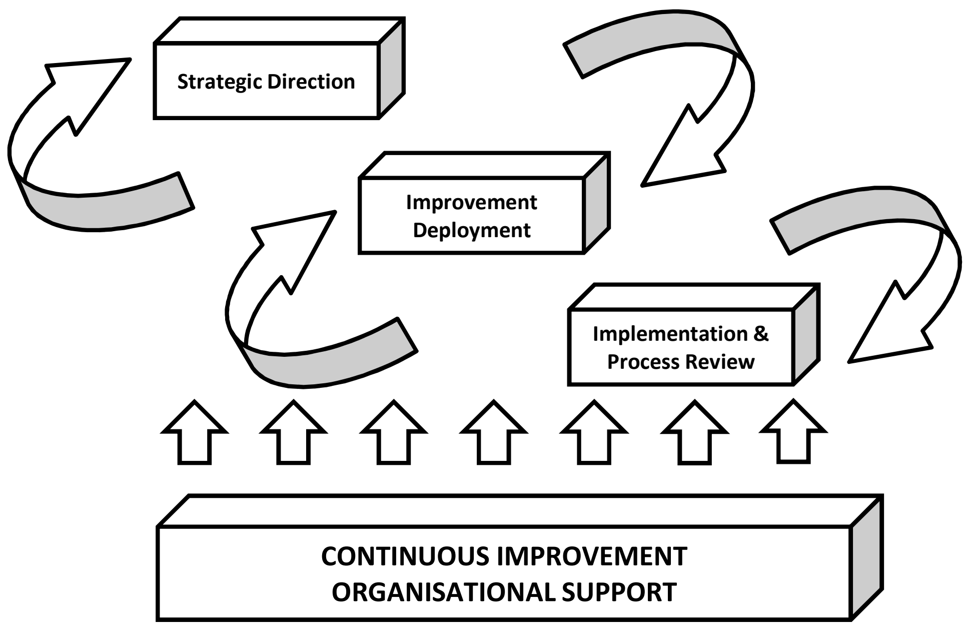


Figure 2 – A conceptual framework for Continuous Improvement
Source:Carpinetti et al (2001:283)

This new model not only has to enable CI practitioners in a process environment to implement the continuous improvement programs successfully, but also stretch these practitioners to their full potential and capability, ultimately creating a climate in which the MBP's will be practising continuous improvement on a daily basis.

1.3 Research problem statement and research objectives

1.3.1 Problem statement

The minerals processing industry is one of the most important industries in the South African economy. A lot of emphasis is placed on the throughput of ore in order to increase production of metal and/or alloys. The same principle applies to all MBP's.

Many companies, including numerous resource companies, have some CI initiatives, but the execution thereof is poor, mainly due to the ill-fit of these programmes. In some cases, the CI programme does not fall within the classical definition of continued incremental improvements to the business, and hence it can rather be seen as long term strategic projects.

All resource companies want to be the preferred investment partner, yet investors rarely deal with stagnant companies, as growth is a measure of success. It therefore becomes inevitable to assume that growth needs to be focussed down to the shop floor in a top-down approach. This growth can only be achieved if improvements are made, and organisations have the competitive edge over their rivals. Implementation of a structured, built-for-purpose, CI programme will ensure this growth is achieved. However, considering the literature on available CI tools, the following questions arise:

- Can a CI programme be successfully applied to an MBP?
- Can a combination of Lean Manufacturing (LM), Six Sigma (SS) and Theory of Constraints (TOC) provide an adequate CI model for an MBP?
- What issues unique to an MBP are not specifically addressed by the abovementioned CI tools?

A problem statement can now be defined:

Current CI tools can not directly be applied to MBP's. It therefore results in no CI effort, which will lead to stagnant plants losing its competitive edge over rivals.

1.3.2 Research objectives

The primary objective of this research is to develop a CI Model that will be directly applicable to MBP's. This will be done by scrutiny of current CI tools and its applicability to an MBP.

The tools applicable to MBP's will be selected and a model will be collated based on a combination of LM, SS and TOC. A secondary objective would be to determine which areas of MBP's are not addressed by this collated model, if any, and develop specific tools to address these areas.

1.4 Type of research

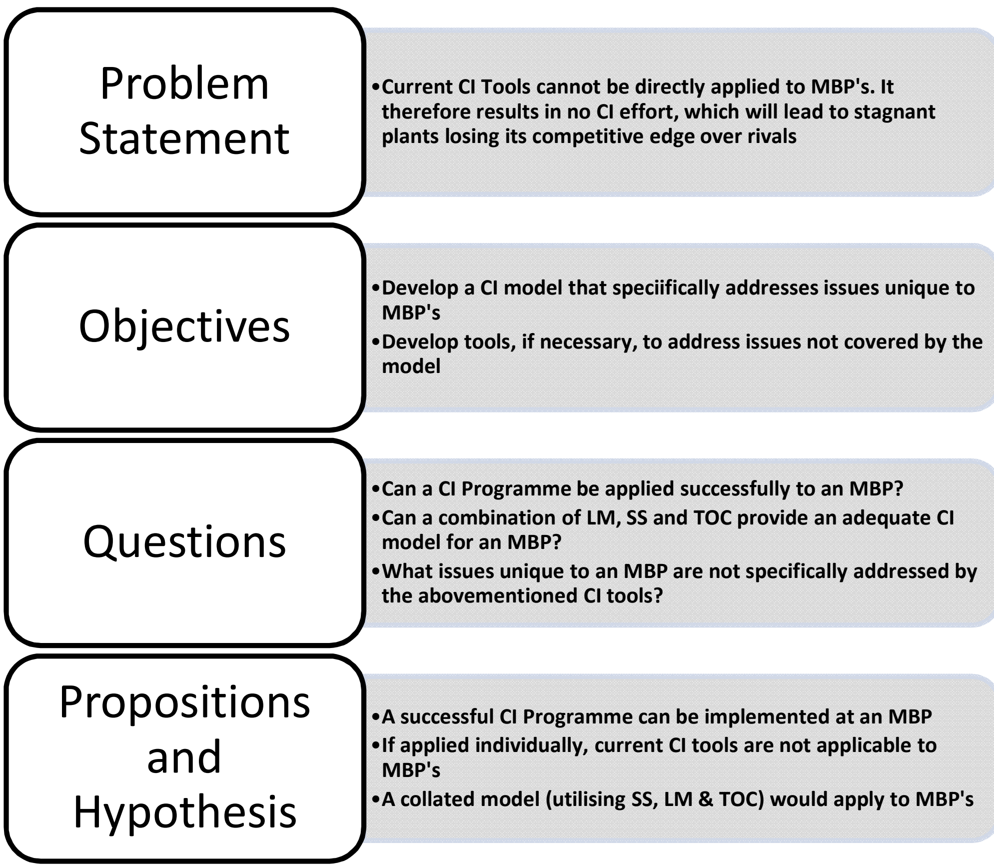


Figure 3– The research problem and objectives summary

1.5 Importance of the research problem

CI is a necessity in business improvement and ultimately business growth. In order to remain competitive, MBP's cannot afford to be satisfied with the status quo. Development of a unique CI model, which incorporates the best elements of SS, LM and TOC, is critical to business improvement initiatives and long term strategy for the minerals processing industry.

1.6 Research Methodology

The research methodology to be used is the development of a non-empirical model, using deductive reasoning, specific experience as well as a thorough literature review.

A survey technique will be used to obtain quantitativedata that will strengthen the quality of the information used to construct the model. According to Fowler (2002:4), data from a survey have three benefits over data obtained from other sources:

- Probability sampling enables one to have the confidence that the sample is not a biased one, and to estimate how precise the data are likely to be.

- Comparable information is obtained about everyone who is described, when standardised measurement is consistent across all respondents.

- A special-purpose survey may be the only way to ensure that all data needed for a given analysis are available and can be related.

Survey questionnaires will focus on existing strategies, to determine what is in use today and what respondents understand of the subject. The survey will be sent to front line managers and supervisors; senior managers; process engineers and metallurgists; management consultants, design engineers as well as CI specialists within various South African Resource Companies, academic institutions and management and mineral consultant groups.

The objective of the survey will be to determine what elements are necessary to develop a CImodel focussing solely on MBP's. The limitation of this model will be that focus will only be on the technical and processing departments within MBP's, and will not consider any service departments such as Human Resources, Finance, etc. Although implementation obstacles will be considered, it will not form part of the main research objectives.

1.7 Outline of Thesis

Chapter 2 is a literature review. Continuous Improvement is defined. The literature review includes discussions on the three most widely used CI models utilised in industry today. Firstlya definition of the specific methodology is given. The aim of the methodology as well as its application is described. The chapter is concluded with a discussion on the selection of a specific methodology for an MBP.

Change management and implementation of a CI strategy is scrutinized in Chapter 3. Some CI structured models and case studies are examined. The important factors for success of CI implementation are shown.

Innovation Management is discussed in Chapter 4. These include the sources of innovation, as well as the principles thereof. The creation of an innovative culture is described.

Chapter 5 includes the rationale of the research as well as the survey instrument being utilised.

In Chapter 6 the survey results are shown and discussed.

The proposed CI model is revealed in Chapter 7. The three phases of the model is described, as well as the six steps to improvement as recommended. Some management tools are also described that will assist the user in successful completion of each step.

Chapter 8 is a case study that was conducted on a Ferro Alloy Smelter using the new CI model. It describes the problem faced by the plant and details how the new model assisted the management team in rectifying poor performance.

Chapter 9 includes the conclusion of the research and discussion on further research.

Chapter 2

"When solving problems, dig at the roots instead of just hacking at the leaves."
Anthony J. D'Angelo

2.1 Literature Study

This literature study will focus on the definition of CI, and the requirements for its successful implementation. The major CI techniques available today will then be discussed individually. An assessment of its applicability to the CI strategy of MBP's will then be conducted.

2.1.1 Defining Continuous Improvement

According to Bhuiyan and Baghel (2005:761), CI is defined as a culture of sustained improvement targeting the elimination of waste in all systems and processes of an organisation. Huda (1994:2) considers CI to be closely associated with Kaizen and defines it as a gradual change, of on-going, unnoticeable improvements which aggregate over a period of time to provide visible proof that things are getting better. Bessant and Francis (1999:1106) define CI as an organisation-wide process of focused and sustained incremental innovation. Another view is presented by Hyland, Mellor, O'Mara and Kondepudi(2000:117) who define CI as a process used by manufacturing firms to improve quality, reduce lead times, reduce price, and improve delivery reliability.

By consideration and collation of the abovementioned definitions, one is able to define continuous improvement as follows:

A focussed approach to improve efficiency of a process, by means of incremental and sustained innovation, resulting in the elimination of waste andenhancement in quality. The core of CI is the principle of modification and adaptation, stemming from human curiosity and the desire to improve things (Bessant, Caffyn, Gilbert, Harding & Webb 1994:17).

The impact of CI on business performance is remarkable, and case studies have shown an increase in profit, throughput, quality and even morale (Bessant, Burnell, Harding & Webb 1993:243-247). A sound CI strategy is essential for an organisation to achieve flexibility, responsiveness and the ability to adapt quickly to changes within its environment (Kaye & Anderson 1999:486).

Probably the greatest advantage CI could hold for MBP's lies in the fact that, if sustained, it will lead to sustainable production. This in turn will lead to cost and time efficiency; product and process quality, effectiveness and reduction in material and energy usage (De Ron 1998:100).

Continuous Improvement is not a new concept, as organisations have always strived for a competitive edge over any rivals. As such, several CI methodologies have been developed through the years. The most widely used methodologies today are:

- Lean Manufacturing (LM)
- Six Sigma (SS)
- Theory of Constraints (TOC)

Each methodology differs in its approach to continuously improve a process and ultimately the business in which it is utilised. LM focuses on waste reduction, SS on quality defect reduction and TOC on asset optimisation.

2.2 Continuous Improvement Methodologies

2.2.1 Lean Manufacturing

"The most dangerous kind of waste is the waste we do not recognize."
Shigeo Shingo

Definition of Lean Manufacturing

LM is defined by Dunstan, Lavin and Sanford (2006:145) as the ceaseless elimination of waste. Dahlgaard and Dahlgaard-Park (2006:264) define it as a philosophy of achieving improvements in the most economical ways with special focus on reducing muda (waste).Muda or waste is defined by Dennis (2002:20) as the opposite of value, which is what a customer is willing to pay for.

Aim of Lean Manufacturing

According to Dennis (2002:19), the aim of LM is to provide the highest quality product, at the lowest cost in the shortest time by reducing waste. In order to understand this concept, it is important to understand waste. According to Bhuiyan et al (2005:763), the aim of LM is the elimination of waste in every area of production and includes customer relations, product design, supplier networks and factory management. Figure 4 shows a diagram that can be used to identity sources of waste.

Ohno, as quoted by Dennis (2002:23) identified Overproduction as the root of all manufacturing evil. Overproduction can be seen as anything that is made, that will not be sold.

It therefore follows that LM is dictated by what the customer requires, and hence follows a pull model. The customer-pull principle and waste reduction will lead to a decrease in production costs, which in return has a positive influence on profit. This is done by a process of continuous improvement.

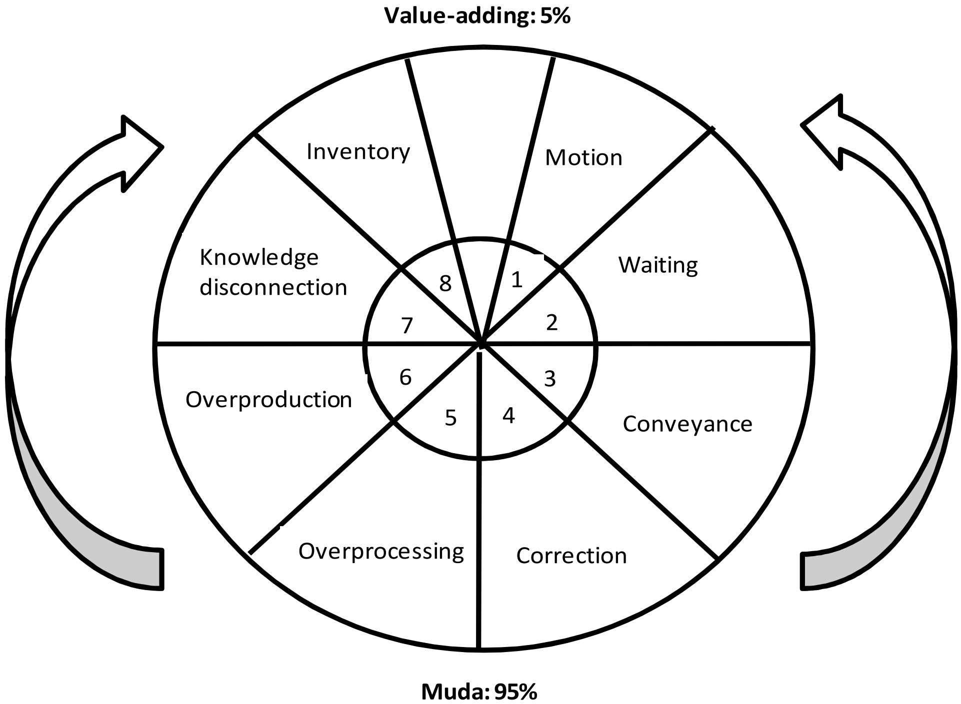


Figure 4 – Identifying waste in a process.
Source: Dennis (2002:21)

LM is a systems approach, and the continuous improvement thereof relies on the stability of the 4M's:

- Man
- Machine
- Material
- Method

The 4M principle is the backbone of the LM way of thinking. Figure 5 indicates how the 4M principle is utilised in a chain-link approach to continuous improvement.

Through proper analysis of each of the 4M's, LM practitioners can identify and define a problem. This problem will then be solved using various problem solving techniques, which in return will lead to an improvement of the process. As mentioned before, the focus area in problem solving is the reduction of waste in all 4M areas.

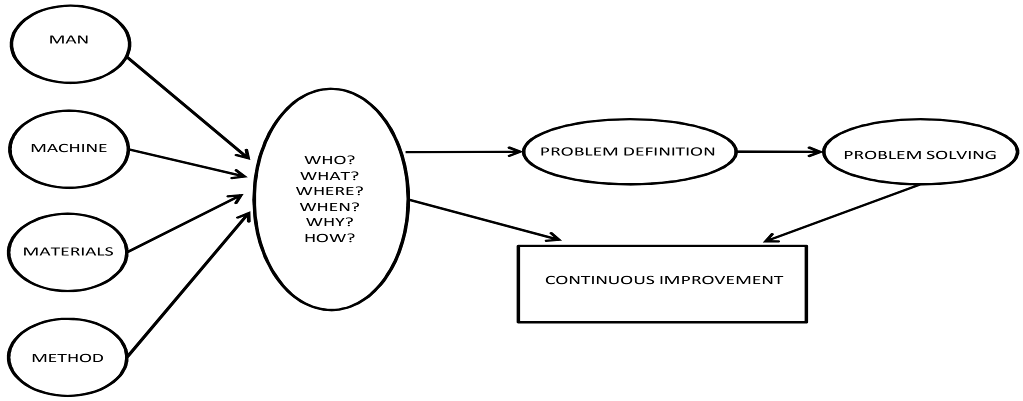


Figure 5 – The LM Chain-Link approach to Continuous Improvement
Source: Huda (1994:38)

This principle of customer orientation and waste reduction will accomplish the goal of LM, which is to reduce human effort, inventory and time needed to develop products whilst becoming highly responsive to customer demand by producing top quality products (Bhuiyan et al 2005:763).

To ensure this goal is achieved, LM applies five basic principles (Andersson, Eriksson &Torstensson 2006:288):

1. Understanding customer value ~ Only what customers perceive as value is important

2. Value stream analysis ~ If business processes do not add value, it should be changed or eliminated

3. Flow ~ Organise a continuous flow through production and/or supply chain

4. Pull ~ No work is carried out, unless the result of it is required downstream

5. Perfection ~ Eliminate non-value adding elements

Application of Lean Manufacturing to MBP's

Since LM is customer driven, it is extremely valuable in a manufacturing environment. Figure 6 shows some of the advantages of LM in a manufacturing industry.

Womack & Jones (in Moore & Scheinkopf 1998:16) states that lean companies work to precisely define value in terms of specific products with specific capabilities offered at specific prices through dialogue with specific customers. This in itself lends a lean company to be driven by the customer. All strategic decisions should be made with the customer and its needs in mind. In fact, in identifying the value stream, one needs to eliminate wasteful activities and products by defining what is valuable to the customer. In its definitive quest to eliminate waste, it also becomes important to the lean company to minimise process flow.

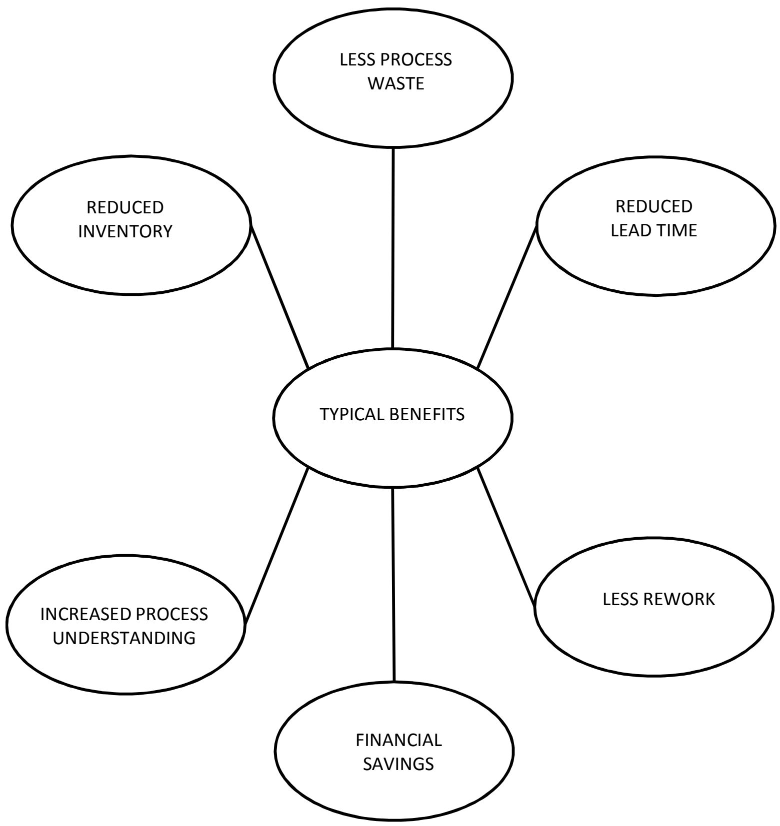


Figure 6 – Some of the advantages that LM can offer

Source:Melton (2005:663)

This is a very important step in LM as it provides the basis for CI. By utilising the 4M's principle, it encourages stability programs such as:

- The 5S System (Dennis 2002:29, Moore et al 1998:19)
  - Sort
  - Set in order

  - Shine
  - Standardise
  - Sustain

- Total Productive Maintenance (TPM)
  - Approach to managing assets that emphasises the importance of operator involvement (Campbell 1995:123)
  - Focused on eliminating losses that downgrade machine effectiveness (Dennis 2002:38)

In a LM environment, inventory is considered to be waste. It focuses on customer demand pulling the product through the system, which in return controls overproduction (Moore et al 1998:19). Over and above this, it strives for perfection through continuously improving the process.

Holweg (2007) showed in his review of lean production, what incredible effect it has had on the Japanese Automotive Industry. The market share Japanese manufacturers had in the US grew from virtually 0% in the 1970's to almost 50% by 2005.

The fact that LM is successful cannot be denied, however it beckons the question whether LM can be applied to an MBP? Some MBP's do not supply to external customers, and final products are very often subjected to further treatment by an internal business unit. Throughput, and not quality, usually drives production in these plants, and value addition only occurs much later in the value chain.

Table 2 shows a comparison between the classic automotive industry (for which LM was designed) and a minerals processing business.

Table 2 – Comparisons between resource/minerals businesses and automotive operations*

Resource Minerals Business	Automotive Business
A smelter if refinery cannot be stopped, so there is inherent production push in the process	An automotive assembly line can be stopped, so there is the ability to create pull systems
Production is in continuous units and around the clock	Production is in discrete units and often less that one day cycles
Inherently variable environment	Stable work environment
Remote locations	Large Centres
Inherently variable raw materials	Controlled raw materials
Geographically spread output teams	Compact plants
Molten material has a short shelf life before it solidifies	Long-life components suitable for supermarket-style storage

***Source: Dunstan et al (2006:145)**

Dunstan et al (2006:145) argue that although LM has its origins in the automotive industry, there is nothing inherent in LM specific to discrete manufacturing processes and, in recent years, it has become a common and effective methodology in many other manufacturing, processing and service industries. This argument is true for some aspects of LM, however literature (Andersson et al 2006; Dennis 2002; Moore et al 1998) states that LM is driven by a customer pull, and not through push in the process, as is inherently true of a MBP. In order to implement LM on a MBP one would have to force fit the programme, by applying the principal of internal customer relationships. This relationship is not always easy to define, as one department could be both customer and supplier. Added to this, LM is a systems approach, meaning that it would have to integrate into all systems on an MBP such as the Safety, Health and Environment (SHE) systems. This will be a difficult and complex task and failure thereof will lead to failure of a CI programme.

Dunstan et al (2006:150) have shown that the implementation of LM has had a significant effect on all aspects of business at its Carbon Bake Furnace situated at Boyne Smelter in Australia. However this was done in conjunction with SS. It is stated that LM was integrated extremely well with the SS project work, and in most cases LM was used in the control phase of SS projects to lock in major improvements.

It is clear that numerous LM tools have applicability in a MBP. Some of these are:

- The 5S System and Visual Management (Dennis 2002:28; Dunstan 2006:148)
- TPM (Dennis 2002:36-43; Dunstan 2006:149; Campbell 1995:123-137)
- Standardised Work (Dennis 2002:51-52; Dunstan 2006:149;Melton 2005:669)

In isolation though, LM would be difficult to implement at a MBP.

2.2.2 Six Sigma

"*Quality means doing it right, when no one is looking.*"
Henry Ford

Definition of Six Sigma

Linderman, as quoted by Brady et al (2006:336) defines SS as an organised and systematic method for strategic process improvement and new product and service development, that relies on statistical methods and the scientific method to make dramatic reductions in customer defined defect rates. Kwak and Anbari (2006:708) define SS as a management approach which is project-driven, to improve the organisation's products, services, and process by continually reducing defects in the organisation. Magnusson et al (in Andersson et al (2006:283)) define SS as a business process that allows companies to drastically improve their bottom line by designing and monitoring everyday business activities in ways that minimise waste and resources while increasing customer satisfaction by some of its proponents. Based on case study data and literature, Schroeder et al (2008:540) define SS as an organised, parallel-meso structure to reduce variation in organisational processes by using improvement specialists, a structured method, and performance metrics with the aim of achieving strategic objectives.

In statistical terms SS can be defined using a quality basis. SS refers to 3.4 defects per million opportunities (Harry 1998:61). It essentially conforms to a quality improvement initiative aiming at the reduction of defects in the production line before it is supplied to the consumer.

Aim of Six Sigma

Bhuiyan et al (2005:763) state that at the heart of SS lies the minimisation of defects to the level of accepting close to zero, and focuses on reducing variation in all the processes of the organisation.

SS is an integrated initiative and success is achieved through a systematic approach using the define, measure, analysis, improve, and control (DMAIC) process (Kwak et al 2006:709). This process is shown in Figure 7.

The DMAIC process is an integral part of the SS methodology. Harry (1998:62) states that each of the steps in the SS approach incorporates key manufacturing, engineering and transactional processes, in order to achieve total customer satisfaction.

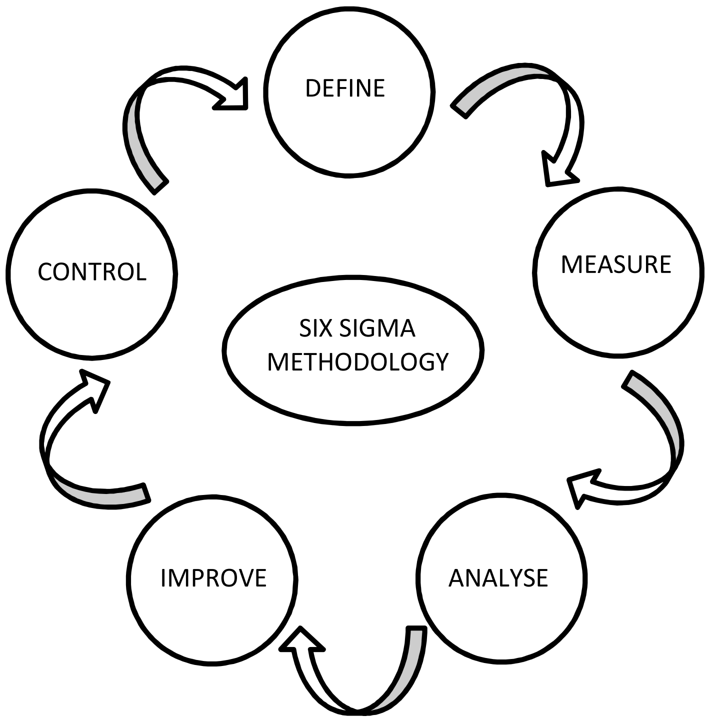


Figure 7 – The six sigma methodology for process improvement incorporating DMAIC

The DMAIC process can be described as follows:

- Define

  Define process that needs improvement, suitable team members, customer requirements and project boundaries. Develop a map of the process that requires improvement (Andersson et al (2006:287); Kwak et al (2006:709)).

- Measure

  Measure process, record results, data collection and estimation of short- and long-term process capability, process issues and shortfalls (Harry (1998:62); Kwak et al (2006:709))

- Analyse

  Analyse factors requiring improvement, causes of defects and variation. Benchmark key product performance metric and prioritise opportunities for improvements. (Andersson et al (2006:287); Harry (1998:62); Kwak et al (2006:709)).

- Improve

  Design and implement the most effective solution in order to minimise variations. It is important to determine key process variables by means of statistically designed experiments and ensure that a cost benefit analyses is done in order to determine the best solution (Andersson et al (2006:287); Harry (1998:62); Kwak et al (2006:709)).

- Control

  Verify success of implementation and ensure sustainability. Re-asses the improvement and if necessary revisit one or more of the preceding steps to continuously improve the process (Andersson et al (2006:287); Harry (1998:62))

Anthony (2004:303 – 304) highlights seven aspects of SS which differentiates it from other quality improvement initiatives. In terms of process improvement at an MBP, three of these are discussed:

- SS focuses on achieving quantifiable financial returns to the bottom-line of an organisation. No SS project should be approved unless the financial impact has been clearly defined and identified. Many companies use the SS methodology due to the positive financial impact (Andersson et al 2006:287).

- SS emphasises the importance of data. Decision making is based on facts and figures. This forces companies to put measurements of key metrics in place.

- SS encourages the use of statistical tools and thinking for defect reduction through process variability reduction methods. It allows for the alignment and integration of statistical tools into a logical, purposeful sequence for critical-to-quality (CTQ) improvement and business competitiveness (Goh 2010:301).

Application of Six Sigma

Clifford (2001:140) states that SS is a full-on corporate fad, and that the bottom-line gains are being exaggerated. This view is disputed by a panel of experts stating that results achieved through a SS programme cannot be ignored (Anthony 2007:18 – 19). Literature shows multiple examples of the positive effect SS has had on process improvement. A summary of some of the quantitative results is shown in Table 3.

Table 3 – Reported benefits and savings from companies utilising the SS methodology

Company	Metric/Measure	Benefit/Saving
Motorola	In-process defect levels, Financial	150 times reduction, $15 billion in 11 years
Raytheon	Depot maintenance, Inspection time	Reduced by 88%
General Electric	Turnaround time at repair shops, Financial	62% reduction, $2 billion in 1999
Honeywell	Capacity, Cycle time, Inventory, On-time Delivery	Up 50%, Down 50%, Down 50%, Increased to nearly 100%
Texas Instruments	Financial	$ 600 million
Johnson & Johnson	Financial	$ 500 million
Volvo	Financial	€ 55 million between 2000 and 2002
Ericsson	Financial	€ 200-300 million between 1997 and 2003

Source:Kwak et al (2006:711) and Andersson et al (2006:287)

The SS methodology was developed to satisfy the need to improve quality. The focus is customer oriented, with improvements aimed at reducing defects in products. This approach does however lend itself to be more receptive to a MBP due to the following core principles:

- Measurement of variables in a process

- Improving bottom-line

- Project Approach

These are elements which can easily be fitted into the operation of an MBP. Mining companies such as BHP Billiton and Rio Tinto have embraced SS as a process improvement tool. Many MBP's strive to be ISO 9000 compliant, making SS a logical choice as quality improvement strategy. ISO 9000 demands continuous quality improvement with a customer focus by using a process approach. These demands correspond perfectly to the philosophy of the SS methodology (Lupan, Bacivarof, Kobi & Robledo. 2005:719).

The fact that SS makes use of a project approach is particularly attractive to an MBP, since most problematic areas in a continuous improvement plant would require a structured approach to identify and implement a solution.

Akser and Tomas (2005:124 – 125) showed that four types of projects typically exist in a heavy minerals plant, which can also be defined as an MBP:

- Process

  A technical project, where concrete evidence of improvements to an existing process are targeted. The benefits of these projects are financial of nature.

- Transactional

  Involves some business functionality such as decreasing defects in accounting. The benefits of these projects are financial of nature.

- Baseline

  Generates knowledge that typically opens up several new financially attractive prospects.

- Top line growth

  The development of new revenue opportunities such as the introduction of a new product line.

Akser et al (2005:125) claims that SS can be applied in all facets of the heavy mineral operations, including maintenance and minerals processing. In terms of maintenance, they have shown a reduction in maintenance repair day cycle time. They have also been able to increase the trommel screen capacity by 87 %, without having to replace the existing screen; a 47 % improvement in dry mill production, and a 3 % yield increase.

It must be noted though that in the wet milling section, the results have been less than desirable, due to the inherent multi-variable (>15 variables) nature of spiral upgrading. This is a concern, since most processes in an MBP consists of multi-variables, often more than 15 variables.

Measuring these variables become quite difficult and the analysis of this data often requires complicated statistics such as Principal Component Analysis and Classification and Regression Trees (Aldrich 2010:32). It may also be a challenge to collect quality data, as some processes might not have any data to begin with (Anthony 2004:304). Added to this, some variables are not measured, or cannot quantifiably be measured.

Bendell (2006:256) argues that SS is particularly effective for manufacturing and simple transactional processes, but a limitation thereof is that it focuses on the use of statistical techniques and other “left-brain” tools, neglecting “right-brain” thinking, creativity and innovation. This theory is supported by Parast (2010:9) stating that SS may impede the ability of a firm for radical innovation, forcing it to pursue the current technological trajectory.

In its current form, SS programs do not guarantee a sustainable competitive advantage for firms due to the fact that it focuses on existing processes, products, and customers (Parast 2010:9). Again this will have a negative influence on improvement opportunities at a MBP, as process deviations often require radical innovations to improve.

Goh (2010:304) claims that one of the "tragedies" of SS is the fact that practitioners often have a "In data we trust" mentality. This is particularly dangerous in a MBP environment, where incorrect data or analysis thereof could have serious repercussions on the process if changes are made based on these results. Logical opinions and experience should always have precedence over statistical outputs.

It is seen that again SS alone cannot be sustainable as a continuous improvement methodology for an MBP. Pepper and Spedding (2010:145-150) suggest the use of Lean-Six Sigma showing a competitive advantage in using a combination of both strategies (See Figure 8).

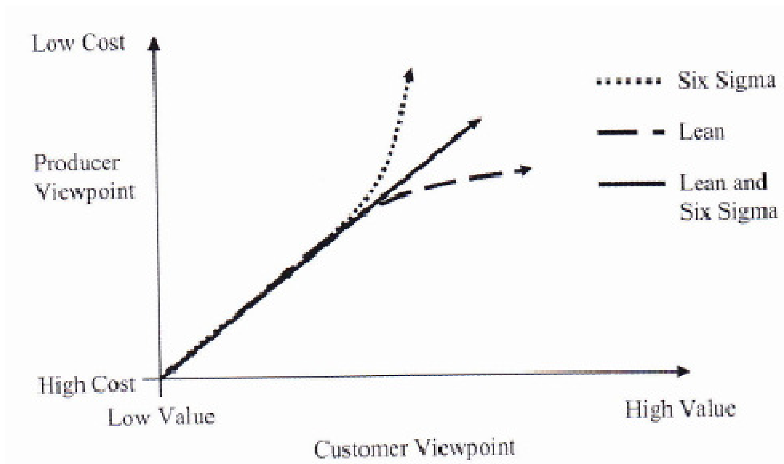


Figure 8 – The competitive advantage of lean, six sigma and lean-six sigma Source:Arnheiter et al (in Pepper et al 2010:148)

Lupan et al (2005:722) suggests integrating SS with Deming's PDCA cycle (which is strongly suggested by ISO 9000). This can be seen in Figure 9.

Another approach is suggested by Ehie & Sheu (2005:542), where SS is integrated with TOC. This is shown in Figure 10.These integrated models may provide an answer to the dilemma caused when considering SS in isolation as a CI strategy for a MBP.

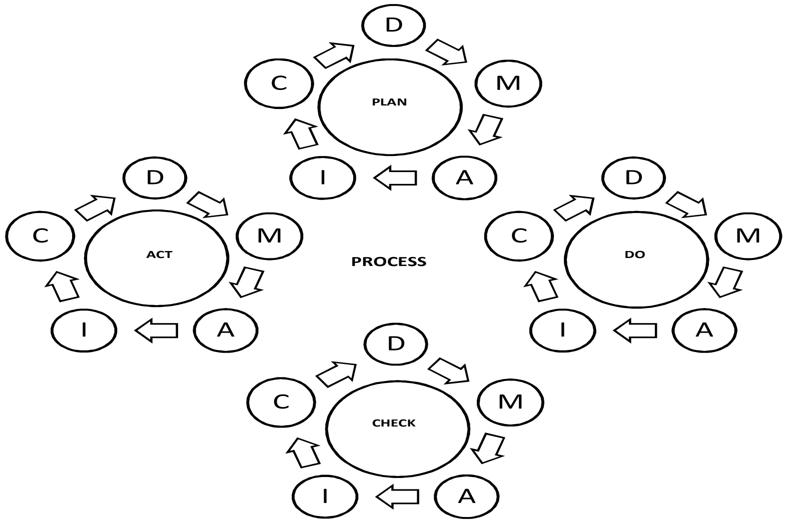


Figure 9 – The DMAIC of Six Sigma applied to the PDCA cycle recommended by ISO 9000

Source:Lupan et al (2005:722)

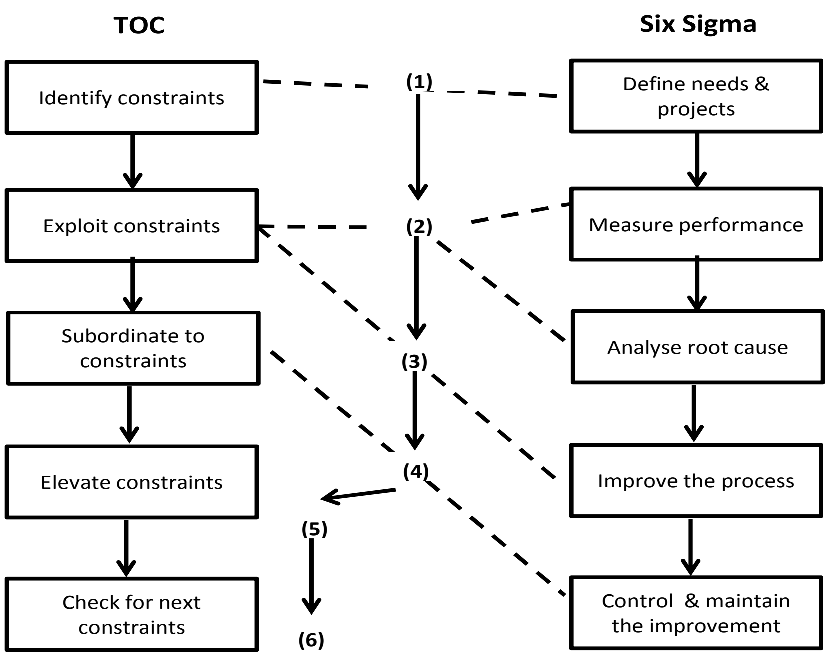


Figure 10 – An integrated approach between six sigma and theory of constraints

Source:Ehie et al (2005:544)

2.2.3 The Theory of Constraints

"Loss in throughput is loss on the bottom line."
Eliyahu Goldratt

Definition of Theory of Constraints

Verma (1996:189) defines TOC as a management approach which focuses on improving bottleneck processes, to continuously improve the performance of manufacturing operations.

A very basic and vague definition is supplied by Schragenheim & Dettmer (2001:13): The theory of constraints is a body of knowledge about systems and the interaction of their component parts which rely on five focussing steps (Identify, Exploit, Subordinate, Elevate, Repeat & Prevent Inertia) to guide the system improvement efforts.

Aim of Theory of Constraints

The principle of TOC is that each organisation has at least one constraint that prevents management from achieving the goal of the organisation (Ehie et al (2005:543)).

TOC provides a strategy for linking the philosophy of CI with the tools which can be used to achieve that improvement (Simons & Moore 1992:2).This is done by trying to answer the following three questions (Verma 1996:189):

- What needs to change?
- What should it be changed to?
- How to cause the change?

It is important to note that TOC is a systems approach, and therefore the term "system" needs to be defined. Schragenheim et al (2001:13) define a system as a group of related elements, enclosed by some arbitrary boundary that differentiates "inside" the system from "outside" - an external environment. This can be seen graphically in Figure 11.

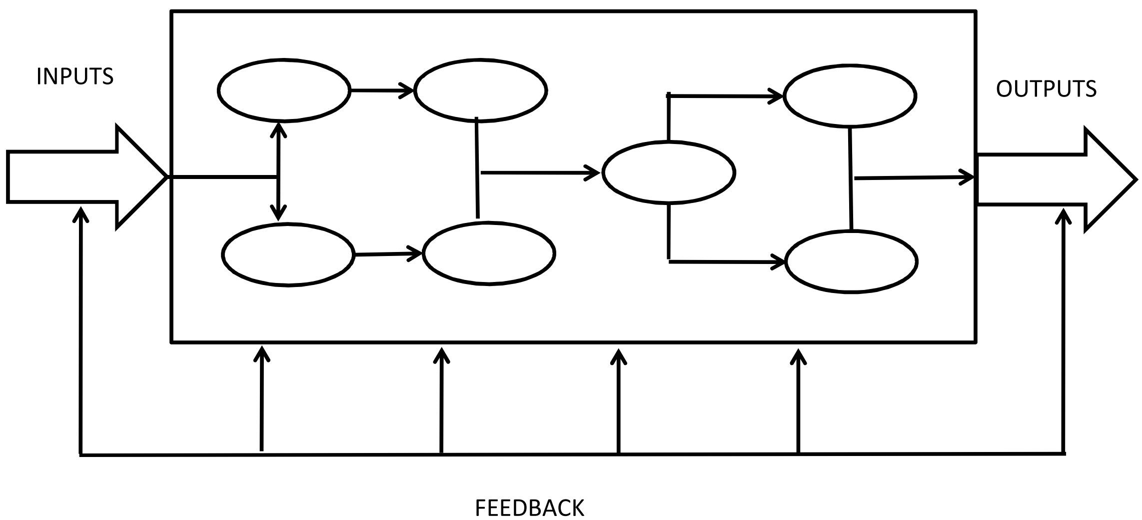


Figure 11 – A generic system

Source: Schragenheim et al (2001:14)

A system takes inputs from the outside, act on them in some way inside the system, and produce outputs back outside the system (Schragenheim et al (2001:14)). It can be seen that all individual processes inside a system have an influence on the system as a whole. It therefore requires for the system to be optimised and improved, not the individual processes.

If any of the processes is a bottleneck, it will adversely affect the whole system. TOC states that a bottleneck is a critical resource, which determines throughput rate, and needs to be utilised 100 % (Chakravorty & Atwater (2006:441)). MBP's operate as a system, consisting of inputs, outputs and interrelated processes.

TOC's approach to managing a system relies on five steps to initiate CI. These steps are shown in Figure 12.

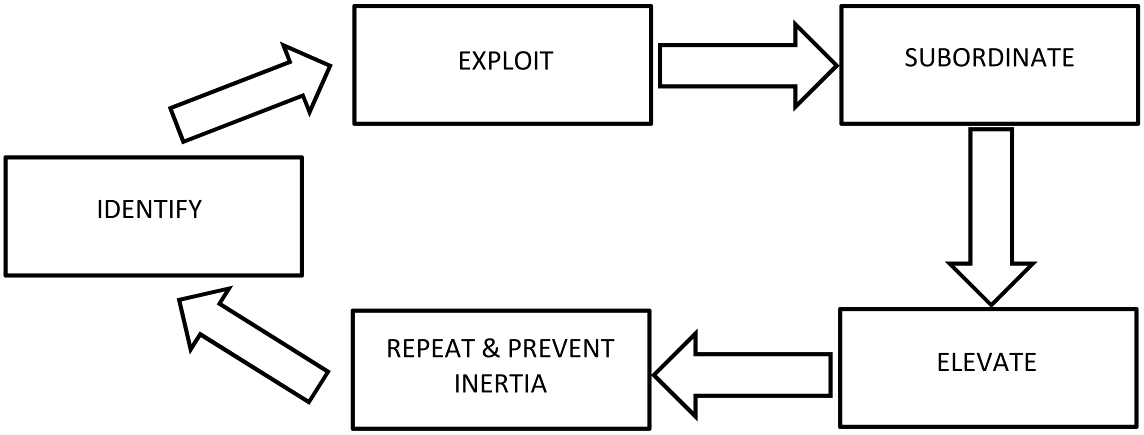


Figure 12 – The five focusing steps in TOC continuous improvement of systems.

- Identify

The most critical step in the TOC programme is the identification of the system's constraint. The constraint is usually the element preventing the system from achieving its goal. Constraints may not be easy to identify and proper analysis of the system will be required to identify the constraints. Failure to correctly identify the system's constraint will rule out success of the improvement process (Simons et al 1992:2). When the constraint is identified, it should be removed. If it is not easily removed, the next step in the programme should be followed.

- Exploit

Since a chain is only as strong as its weakest link, it would make sense to strengthen the weakest link, in order to strengthen the chain. The same principle applies to TOC. By exploiting the constraint, one pushes the constraint to its limit, i.e. get the most out of the constraint without additional investment (Schragenheim 2001:32). Simons et al (1992:3) state that any loss in constraint utilisation will lead to a reduction in success of the whole system.

- Subordinate

Everything else in the system needs to be subordinated according to the constraint identified and exploited in steps 1 and 2.

All other parts of the system essentially become supporters to the constraint (Schragenheim 2001:33). Goldratt (2003:55-58) states that one should be careful of chasing efficiencies, as a desire to have a good departmental performance could clash directly with the desire to have good plant performance – Good global results are not equal to the sum of good local results. This concept basically means that if output from a non-constraint is followed by processing by a constraint, it makes no sense to output more than the constraint will be able to handle (Simons et al 1992:3).

- Elevate

It is important to continuously evaluate the system to determine whether the original constraint is still the system's constraint after step 3. If not, the process should be restarted at step 1. If it is still the system's constraint, step 4 states that it should be elevated.

This approach aims to increase capacity on the constraint (Schragenheim 2001:34). Again, when elevating the constraint, that effect on the whole system should be analysed first.

This is the first step in the process where an organisation can spend money on increasing capacity, however it is very often seen that system performs adequately by implementing step 1 to 3 (Simons 1992:4).

- Repeat and beware of inertia

After the subordinate and elevate steps, one needs to start at step 1 again in order to identify the new constraint, or to verify that it has not migrated away from the original location (Schragenheim et al 2001:37).

This process of "recycling" determines whether the improvement is continuous or a once-off (Simons et al 1992:4). It is however critical to ensure that the system does not suffer from inertia. According to Schragenheim et al (2001:37) there are two reasons for this:

- If the constraint moves, the actions and policies put in place to exploit and subordinate to the old constraint may no longer be the best option for the system.

- There is a tendency to be complacent about the problem since the "solution" has been found. If one does not revisit implemented solutions often, the performance of this system will not continue to improve.

Application of Theory of Constraints

Various organisations have implemented TOC with great success. Ford's Electronic Division implemented TOC, which enabled them to reduce floor space requirements to a point where two additional plants were not required anymore (Simons et al 1992:4). Pegels & Watrous (2003:302,311) showed, that even though they do not view TOC at the forefront of CI technology anymore, it still provided a 26 % decrease in the time required for a production mechanic to complete a mould change in a factory producing heavy-duty truck replacement components.

TOC has a strong inclination for manufacturing plants, although the theory does seem to have some flaws. Chakravorty et al (2006:445 – 446) showed that efforts in utilising the constraint 100 % in a door manufacturing facility culminated in disastrous results for the system as a whole. It is claimed that any advocating of 100 % utilisation of a constraint needs to be halted, as it is a wasteful activity. It is also stated that there is an optimal utilisation, and that this is the number that should be pursued.

Again, the question arises whether TOC could be applied in an MBP or any other processing plant that runs continuously.

Rosolio, Ronen and Geri (2008:4349) did a case study on a dynamic expert system based on TOC, implemented at an oil refinery in Israel. The impact of the programme on the refinery's throughput is shown in Figure 13. Even though the implementation of this system was deemed a challenging task, the result of managing the refinery's constraints, lead to more than $3 million of benefits in the first two years of use.

Goldratt (1997) suggests in his business novel, *Critical Chain*, that TOC principles can easily be applied to Project Management. Rand (2000:174) states that TOC provides a good alternative for Critical Path Method (CPM) and the Programme Evaluation Review Technique (PERT). This may prove to be much more valuable to an MBP than a standard implementation of TOC in the production environment.

The logic behind the use of TOC in Project Management, is the fact that it views the project as a whole, not as individual tasks and activities. The buffers placed in the planning (completion-, resource- and feeding buffer) are designed to ensure that the project is completed in time. Simulation results from work done by Blackstone, Cox and Schleier (2009:7042) are shown in Table 4.

Clearly the CPM/PERT method is outdone by combination with TOC. Added to this, in traditional project scheduling, the critical path ignores resource allocation, which has to be done in a separate step.

The TOC approach takes resource availability into account, by scheduling activities done by the same resource in series (Steyn 2002:76). In an MBP, one resource will probably be working on multiple projects at the same time. Scheduling of resources therefore becomes difficult. Steyn (2002:77) argues that the TOC principles can be successfully applied in resource scheduling of multiple projects.

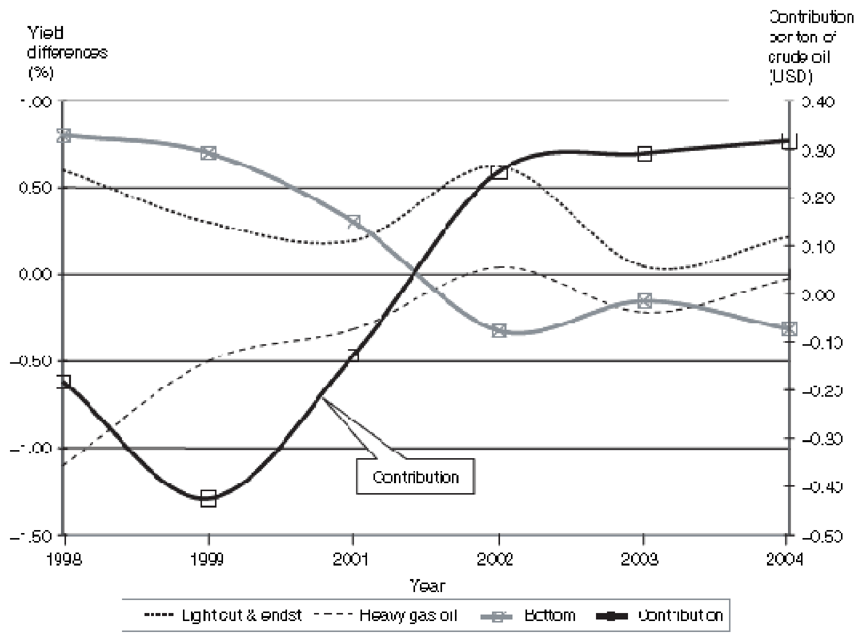


Figure 13 – The impact of process control improvements through implementation of TOC on an oil refinery's throughput

Source:Rosolio et al (2008:4363)

This view is echoed by Viljoen (2002:498), stating that an organisation can utilise limited resources for increased value through the design and management of an integrated value acquisition and delivery process.

Table 4 – Simulation showing average project duration with exponentially distributed tasks*

	Critical Chain	Traditional
Mean	36.073	51.567
Minimum	14.972	45
Maximum	99.048	102.996

***Source: Blackstone et al (2009:7042)**

The method proposed is Critical Chain project scheduling, and synchronisation of projects around the schedule of a heavily loaded resource, as a finite capacity management, that enables leveraging value with scarce resources.

The advantage of this technique is that an organisation can maximise the number of projects without having to jeopardise the principles of reducing project duration on individual projects. This would be an ideal tool for an environment where technical specialists need to devote time to more than one project simultaneously.

2.3 Continuous Improvement Technique Selection

From the literature review on current CI techniques available, it is clear that an MBP would require a unique approach due to the following reasons:

- MBP's run on a continuous basis
- There is no clear market pull at shop-floor level
- Quality is not the main objective – Throughput of material is
- Process improvement is necessary, not product improvement
- Large variations are prevalent due to variance in raw materials
- Variations in constraints – Very dynamic system
- There are limited resources
- Plants operate with large pieces of equipment
- There are usually less processing steps compared to a manufacturing plant
- All the required data are not always available – Some variables difficult to measure
- Data that is available is not always accurate, and often unpredictable

- The process is inherently unstable

Even though implementing any of the CI tools, described earlier, directly to an MBP would probably not address the core issues at hand, it will not necessarily be a complete failure.

The reason for this is that manufacturing plants and MBP's essentially have the same objectives – growth, improvement and profitability. Many of the tools applied in manufacturing plants, can be directly applied to MBP without any force fitting.

It therefore becomes clear that a combination of SS, LM and TOC might deliver a CI model ideal for an MBP. By utilising a survey technique, questioning some key industry players, the CI need will be identified. Using the data obtained from these questionnaires, the specific tools available in the described CI techniques, that are applicable to address the need identified, will be selected to form part of the CI strategy.

Chapter 3

"Change is such hard work!"

Billy Crystal

3.1 Change Management and Implementation of CI Strategy

Although implementation of the developed CI strategy fall outside the boundaries of this research, it is important to consider some change management principles as well as some implementation literature, in order to obtain knowledge on learnings from previous experiences.

Zink, Steimle and Schröder (2008:528) state that whenever a change initiative is undertaken, the logical (objective) and psychological (subjective) dimensions need to be integrated. A simple model of this integration is shown in Figure 14.

Zink et al (2008:528) explains that the objective dimension (in Figure 14), needs to include a strategic alignment of all change initiatives, within an integrated overall concept. Similarly, in the subjective dimension, it is critically important that employees' understanding of the relationship between the organisation's strategy and the planned change initiatives, is good in order to create a climate of acceptance amongst employees.

The integration between the objective and subjective dimensions is key to a change initiative's success, since participation of employees guarantee an understanding of the challenge of subjective integration from the employees' perspective.

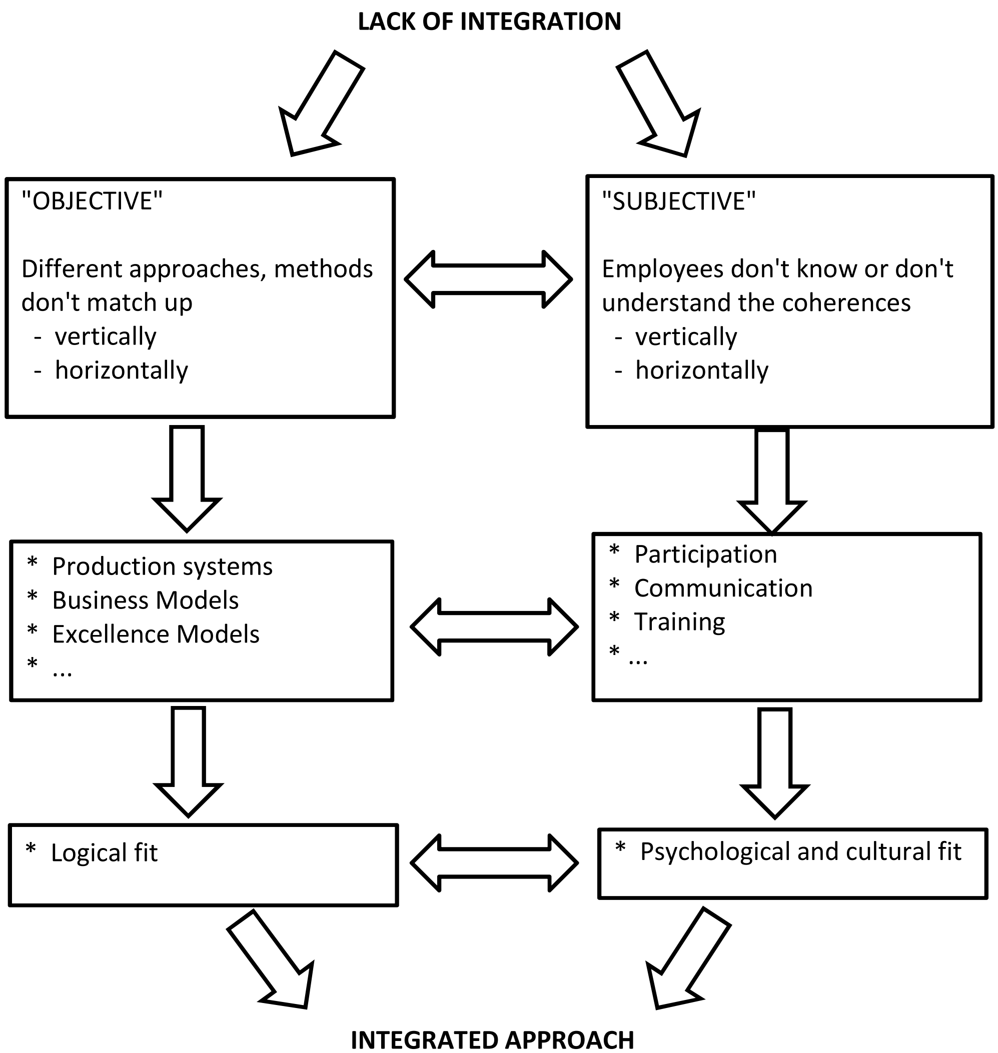


Figure 14 – A simple change initiative integration model

Source: Zink et al (2008:528)

Hayes &Pistano (1994:78) argue that change initiatives (such as CI initiatives), should never be used as solutions to specific problems, but rather as stepping stones in an intended direction. They state that a competitive strategy is about staking out a position, whilst a manufacturing strategy (such as LM etc.) focuses on getting better at the things necessary to defend that position. This competitive strategy needs to be accompanied by a vision and appropriate values.

This vision should be developed by senior management, who also has the responsibility to achieve change through consultation rather than by diktat (Price & Chahal 2006).

This change can be traumatic for employees, and typically all employees will show signs of Kubler-Ross's response cycle to change and/or loss (Kubler-Ross in Price et al 2006:242) which are, denial, anger, bargaining, depression and acceptance.

One way of easing the traumatic response to change is for the organisation to ensure that all of its employees at all levels are involved in the process (Ljungström 2005:385). There are different models that can be used to implement CI as well as ensuring involvement of all employees in the process.

Wu & Chen (2006:700) suggest the use of an integrated CI structural model (Figure 15), which incorporates, the problem statement, the model and tools to be used, the promotion of the programme, as well as interaction between these elements through all spheres of the business.

Ljunström (2005) proposes an implementation model consisting of five steps:

1. Project Consolidation

2. Management Training

3. Identification and Training of Facilitators

4. Team Training

5. Support

What is important to note, is that proper regenerative input needs to be injected before an activity declines (Wu et al 2006). This will ensure continuous improvement of the process and or system. Figure 16 shows the typical activity life cycle, to which an improvement programme also subscribes.

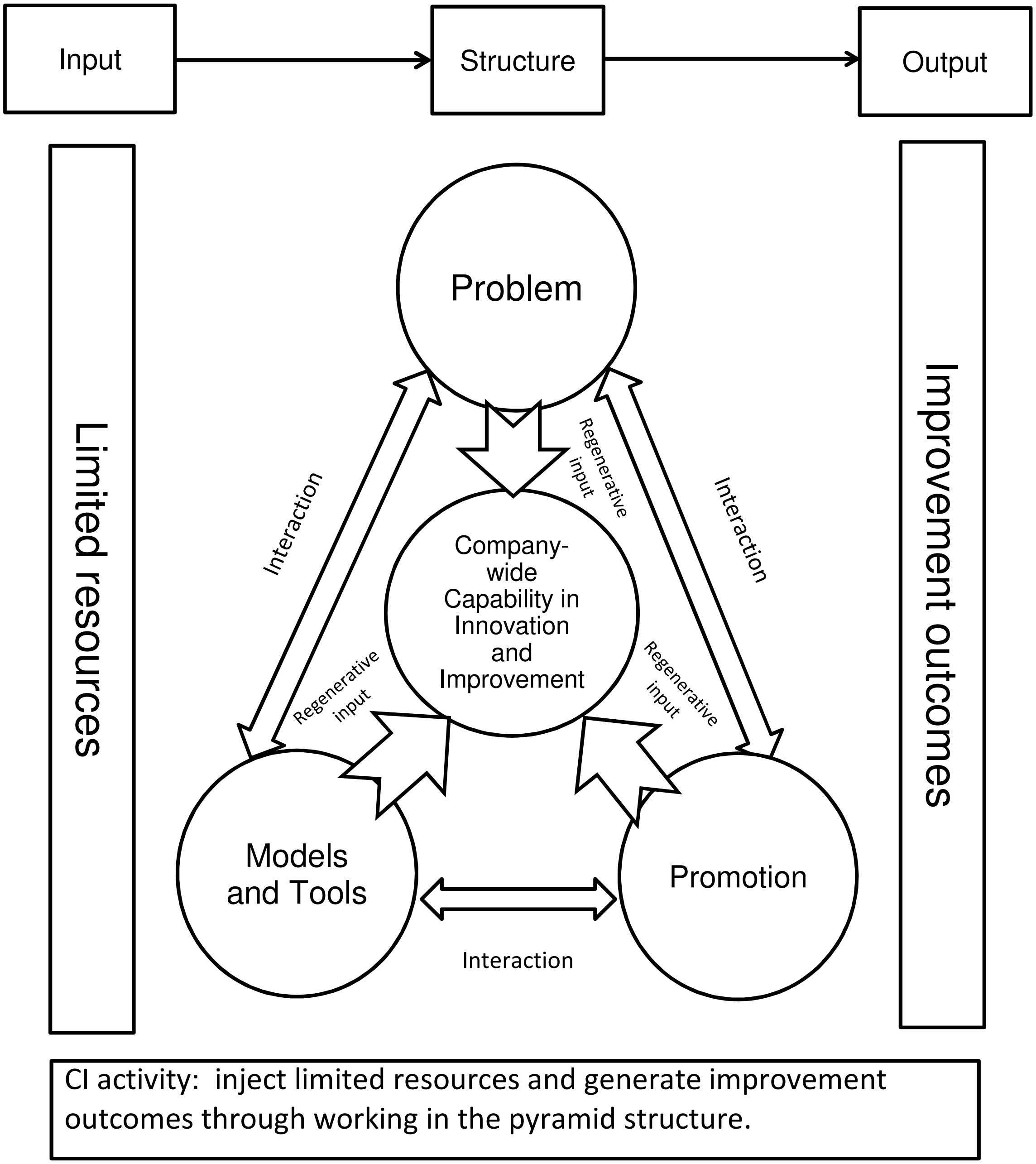


Figure 15 – The integrated CI structural model proposed by Wu et al (2006)
Source: Wu et al (2006:700)

A number of research articles have been published on the subject of CI implementation. De Jager; Minnie; De Jager; Welgemoed; Bessant & Francis (2003:315) state that CI should be a systematic process of organisational development, in which the facilitative patterns of behavioural routines are extended and reinforced, to enable a major culture change.

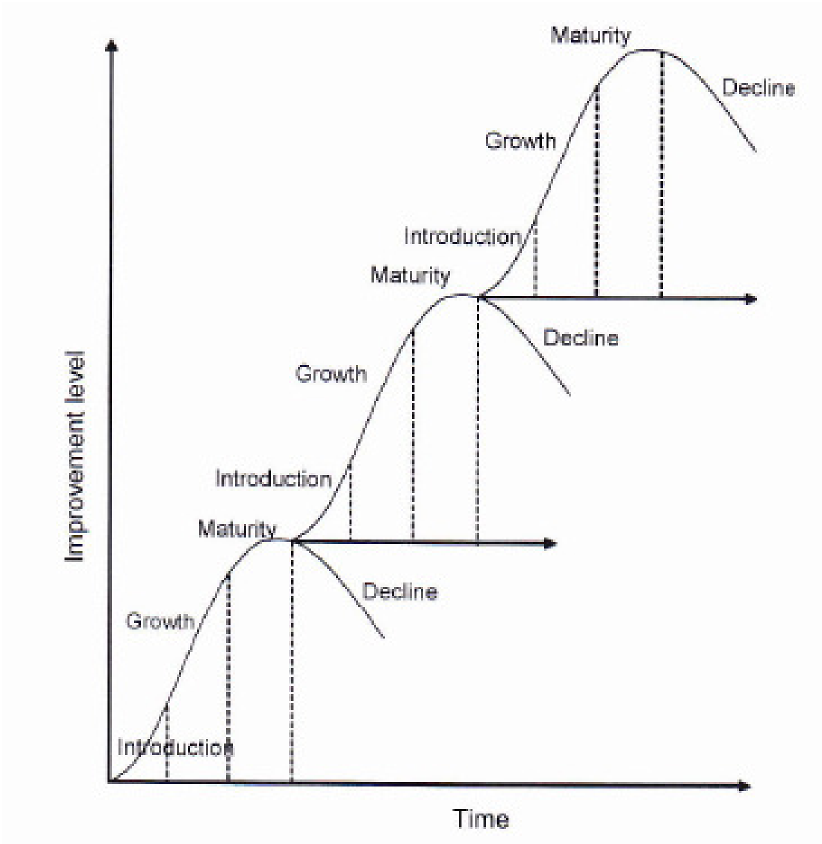


Figure 16 – A typical activity lifecycle

Source: Wu et al (2006:698)

The case study presented by De Jager et al (2003:318), is based on their experience with the implementation of CI at Kumba Resources, a major producer of iron ore and, at that stage, both metallurgical and thermal coal. They highlight four learnings from this implementation:

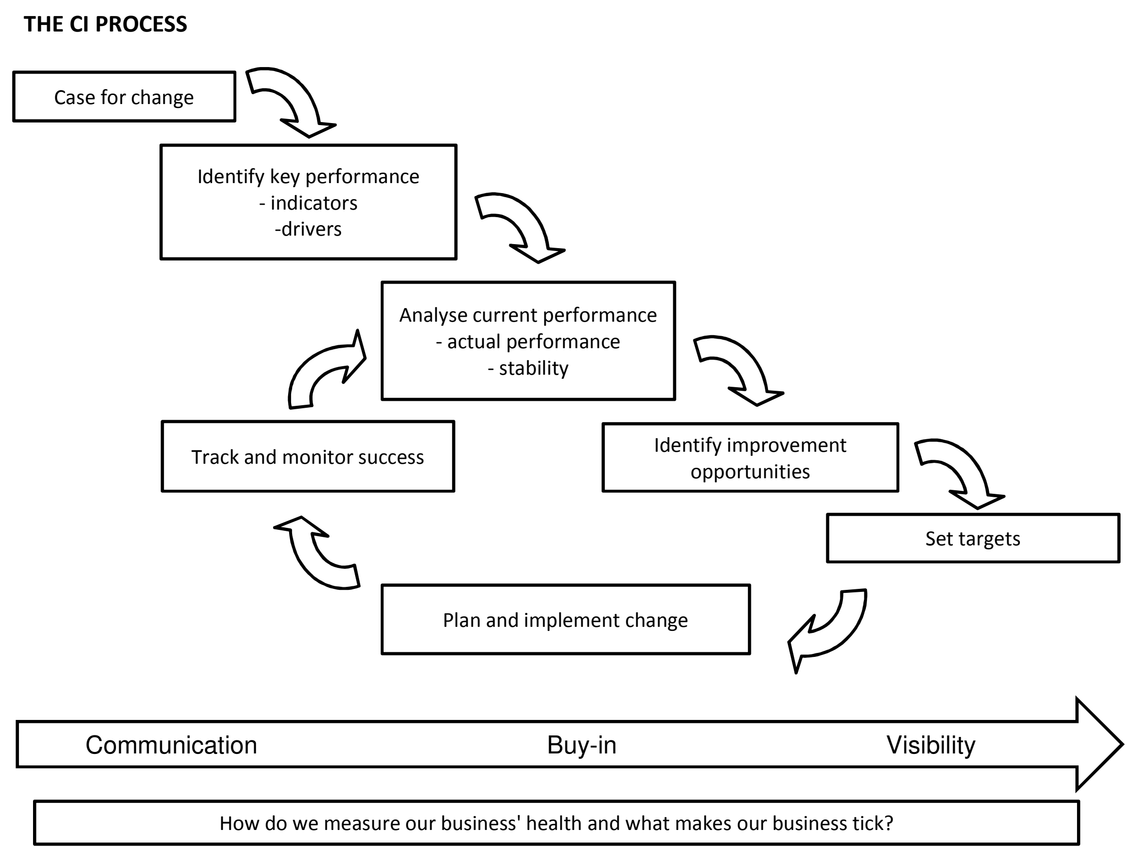
1. Ensure the focus group understand the model, and its working environment

2. Ensure that at least one moderator has a clear understanding of the group's frame of reference

3. Use a common language and terminology

4. Make use of translators to improve effectiveness.

The most important point highlighted by De Jager et al (2003:323), is to ensure that there is proper goal alignment between the implementation team and the shop floor. The model utilised in this case study is shown in Figure 17, and the emphasis on communication and buy-in from the shop floor can be clearly seen.



Note: Key Performance Indicators and Drivers were identified in order to focus performance analysis.

Figure 17 – The CI wheel utilised during the implementation of CI at Kumba Resources

Source: De Jager et al (2003:321)

De Jager et al (2003) have done very important work in understanding the dynamic involved when implementing CI in the South African mining industry.

Jakelski & Lebrasseur (1997:172) have done research on the implementation of CI in the North American mining industry. They found the five most important factors for success of CI to be:

1. Employee Buy-in
2. Corporate Presence
3. Customer-oriented Strategy
4. Historical Fit
5. Practical Goals

It becomes clear from literature that employee involvement is the core to any CI programme's success. It is also very important to have goal alignment between management and the shop floor, as well as a committed senior management team. A well-defined and well communicated vision and values will provide the cornerstone for goal alignment within the organisation. In the South African context, one needs to be sensitive to cultural barriers, such as language etc., and the framework in which CI falls needs to be clearly defined.

Chapter 4

"It's easy to come up with new ideas; the hard part is letting go of what worked for you two years ago, but will soon be out of date."
Roger von Oech

4.1 Innovation Management

Innovation is the act that endows resources with a new capacity to create wealth (Drucker, 2005:27). Baregheh et al (2009) define Innovation as a multi stage process whereby organisations transform ideas into new/improved products, services or processes, in order to advance, compete and differentiate themselves successfully in their marketplace. According to Terziovski and Sohal (2000:540), improvement consists of both CI and Innovation. It is argued that CI is small improvements made as a result of on-going effort, whilst innovation is seen as a step-change improvement in the status quo. It need not be technical in nature, and can consist of a system or social change. It must be stated though, that if organisations, including MBP's, desire to be leaders in its specific field, continuous innovation in products and process is the best strategy (Nijhof et al 2002:675). Drucker (2005:31) defines four sources of innovation from within the organisation. These four sources are as follows:

- The unexpected – the unexpected success, the unexpected failure, or the unexpected outside event

- The incongruity – between reality as it actually is and reality as it is assumed to be or as it ought to be

- Process need – Innovation based on process need

- Industry and/or market structure – Changes in the industry or market structure that catch people unaware.

According to Drucker (2005:123 – 125) the principles of innovation include the following:

- Purposeful, systematic innovation begins with the analysis of the opportunities
- Innovation is both conceptual and perceptual, meaning that both the left and right sides of the brain should be utilised in the innovation process.
- An effective innovation has to be simple and focussed.
- Effective innovations are not extravagant, but start small.
- A successful innovation aims at leadership.

If an organisation aims to be regarded as innovative, it needs to prescribe to an environment that is conducive to creative thinking. The three conditions proposed by Drucker (2005:126) are as follows:

- Innovation is work – Innovation requires hard work, knowledge and ingenuity. If hard, focused, purposeful work is lacking, no amount of talent, ingenuity, or knowledge will avail.
- Innovators need to build on their strengths – Successful innovators identify opportunities that fit the innovator, the company and have shown capacity for performance. Employees and employers will only do well with opportunities if it is respected.
- Innovation is an effect in economy and society – Innovation is the process of change.

4.2 The Innovative Culture

The failure rate of CI programs, involving employees, is high (Bessant et al 2001:67). Imai and Beer in Nijhof *et al* (2002:675) argue that various innovative ideas suffers from a lack of dedication and confidence in the success of the idea, and might even be aggravated if the originator is excluded from the development of the idea.

It is for this reason that Nijhof *et al* (2002:680) proposes the strategy of excusing the idea generator from his permanent position, in order to be part of the implementation team. This principle allows an innovative climate in which a bottom-up approach is followed, yet no formal structures are in place. This approach has the advantage of providing trust in employee ideas, as well as securing commitment to innovativeness, but without proper structure to support this venture, it may not be as successful in a large organisation such as an MBP. Irani & Sharp (1997:202) state that an organisation with a horizontal management structure, open culture and empowered employees create the atmosphere for CI and Innovation. These characteristics include:

- Easy access and flow of information
- Close lateral and vertical working relationships between cross functional departments
- Team work with shared credit
- Full support from the management team with an absolute commitment to CI and innovation

In today's competitive environment, and with all the constraints experienced by MBP's, innovation may just be the key to achieve an edge over rival organisations. It is important to note though that an innovative climate has to be established. This can be achieved through the concept of exemption as proposed by Nijhof *et al,* yet other, less radical ideas, would bear similar fruits. The bottom line remains that innovation is an essential part of CI, and employee involvement, in whatever form, is crucial.

Chapter 5

"Strive for Continuous Improvement, instead of perfection."

Kim Collins

5.1 Rationale of the Industry Survey

The purpose of the industry survey is to provide astute information regarding the Minerals Process Industry viewpoint on Continuous Improvement. The information attained through the survey would then be utilised to develop a model that can be directly applied to a MBP.

5.2 Survey Compilation

The survey consists of three sections – Background information of respondents; knowledge of established CI methodologies and industry requirements for an improvement methodology.

The respondents were questioned on several aspects addressing background. This included experience, management level, as well as the type and size of organisation that they are employed in. The aim was to gain an understanding of the focus group, and therefore be better enabled to draw conclusions from the results obtained.

Since it was decided to focus mainly on three improvement methodologies, the respondents were questioned on their understanding thereof. This provided a basis for the focus group's experience in working with these methodologies, as well as gaining information on the preferences in technique. Information was also sought to determine whether any of the respondents have been involved in utilising a methodology in an MBP, as well as determining the success or failure of these attempts.

The respondents had the opportunity to answer some questions related to the preferences they have with relation to improvement objectives in an MBP.

This information was critical in the development of a new CI model, as the aim is to address specific issues raised by the respondents, as well as aligning with expectations from a CI perspective

The information obtained focussed on the following:

- Background information of respondents
- Industry experience of respondents
- Knowledge of CI and related strategies
- Need for CI in MBP's
- Driving forces of CI in industry

5.3 Survey Instrument

A web based electronic survey was used to obtain information. The survey was hosted on www.surveymonkey.com.This survey was e-mailed to several people employed by major South African mining and resource organisations, academic institutions, technical consulting houses as well as some management consultants. The mailing lists comprised of personal contacts, as well as information received from administrative and human resources departments within these organisations. In order to reach more respondents, the survey was also hosted on the University of Pretoria's Metallurgical Engineering Alumni Facebook page.

The questions within the web survey were set up in distinct categories that would provide information on how the industry perceived CI as well as whether there is a place for CI in a MBP. It is also specifically tested the respondents knowledge of SS, TOC and LM.

As the survey targeted a specific group of individuals who either work on or have worked within the minerals resource industry, the pool of respondents were quite limited. In total 80 respondents completed the survey.

The survey instrument provided for accurate information gathering, as answers were limited by questions. The margin for error was therefore drastically reduced.

Survey data was summarised and downloaded from *Surveymonkey* in spread sheet form. All comments were carefully read and analysed, before being arranged in specific data sections. This was then transferred into graphic form, from where data analysis occurred.

Chapter 6

"Change is the end result of all true learning."

Leo Buscaglia

6.1 Electronic Survey Results

6.1.1 Background Information of Respondents

Figure 18represents the composition of the industry that the respondents represent. The majority of the respondents (47%) work in a Pyro Metallurgical environment.
This is followed by respondents working in Minerals Processing (20%) and Resources Industries (16%). Hydro Metallurgy accounted for 6% of respondents. There were some respondents working in other industries not directly relating to a processing facility. This included Management Consultants, Technical Consultants and the Oil and Gas Industry.

Even though a large majority of respondents are employed within a smelting environment, the principle of mineral beneficiation remains solid within the minerals processing, hydrometallurgy as well as oil and gas industry. It would be a fair assumption that the requirements of all respondents would be similar with regards to CI as these plants, are operated within similar boundaries.

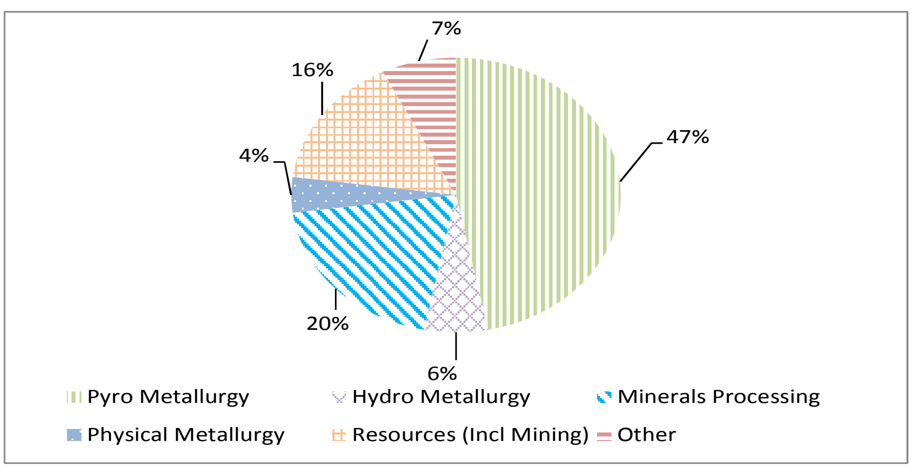


Figure 18 – The industry respondents are employed in

It is seen in Figure 19, that 40% of respondents have more than 10 years' experience, with 33% having less than 20 years' experience. The majority of respondents (60%) have less than 10 years' experience. The majority of training programmes for professionals within the minerals resources industry spans for approximately 2 years, from where active participation in process and people management is the norm. Thus, it can be assumed that a decent spread of experience level was reached.

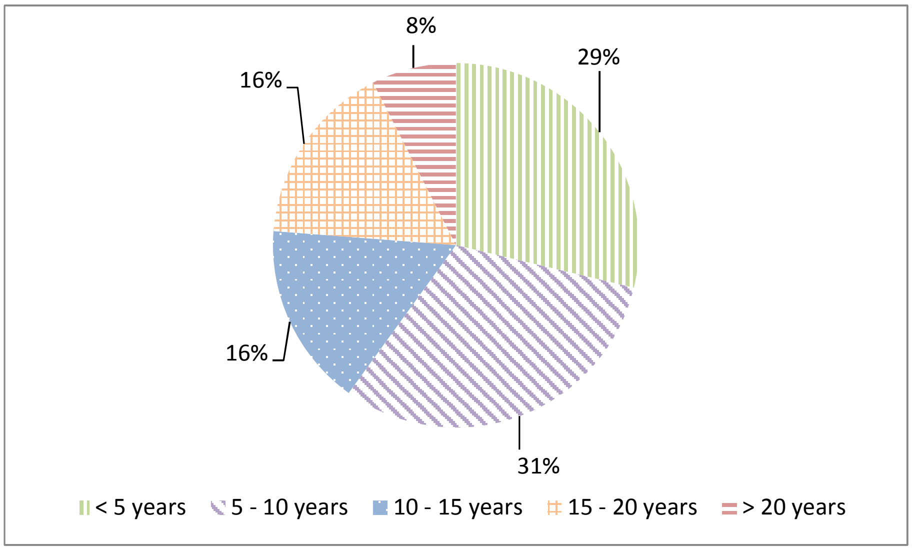


Figure 19 – The experience level of respondents

Even though the majority of respondents have 10 years or less experience, it was found that 74% fulfil a middle or senior management role in the respective organisations they are employed in. Junior management and Patterson C-levels constitute about a quarter of the respondents, whilst General and Executive Level were 6%. The fact that respondents do not have a lot of experience in years, is countered by the management positions they occupy within their organisation. These results are shown in Figure 20.

The majority of respondents are between Junior and Senior Management. This is significant, as it represents the core of management that would be involved in managing an MBP. This group of employees will have first-hand knowledge of the requirements for CI programmes focussed on MBP's.

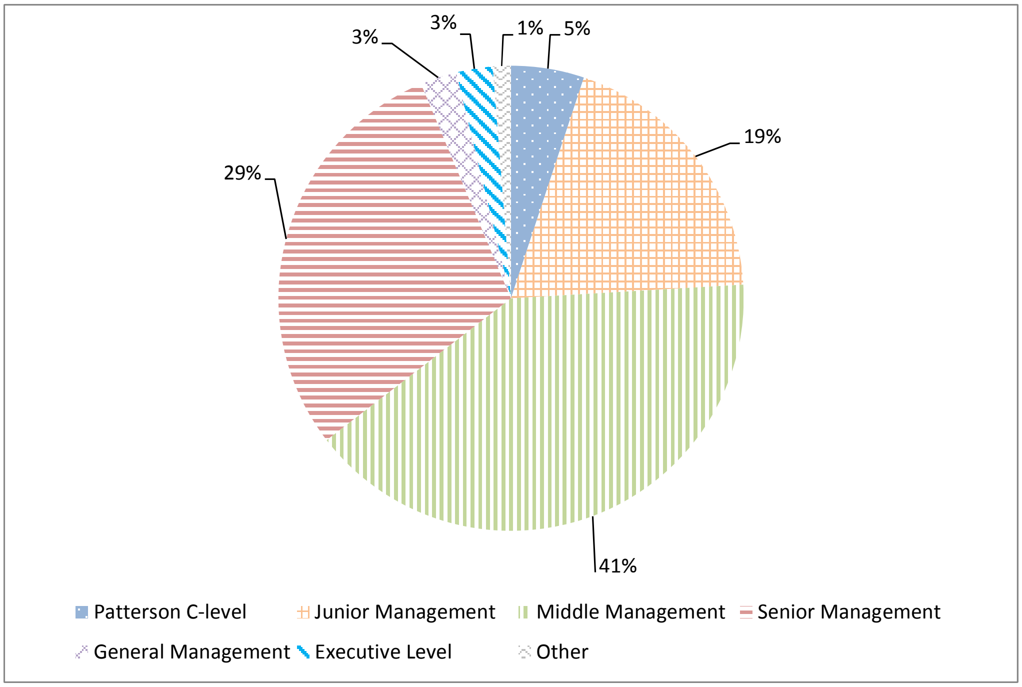


Figure 20 – Level of management occupied by respondents

Figure 21 represents the composition of the primary function of the respondents within their organisations. A well balanced spread is observed between functions. Quite a number of respondents (13%) selected "Other" to describe their current role. Figure 22 shows a breakdown of this with the majority of these respondents in a consulting role.

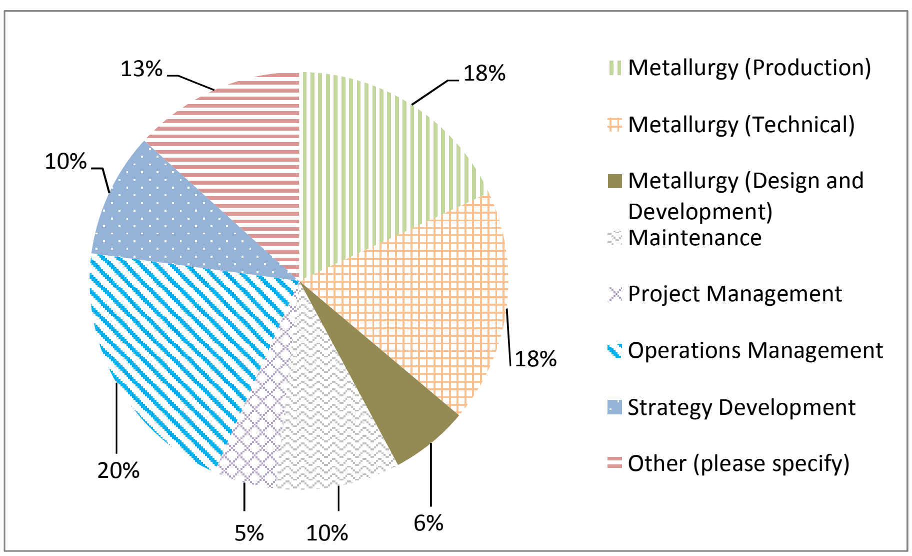


Figure 21 – A breakdown of the respondent's primary function within the organisation

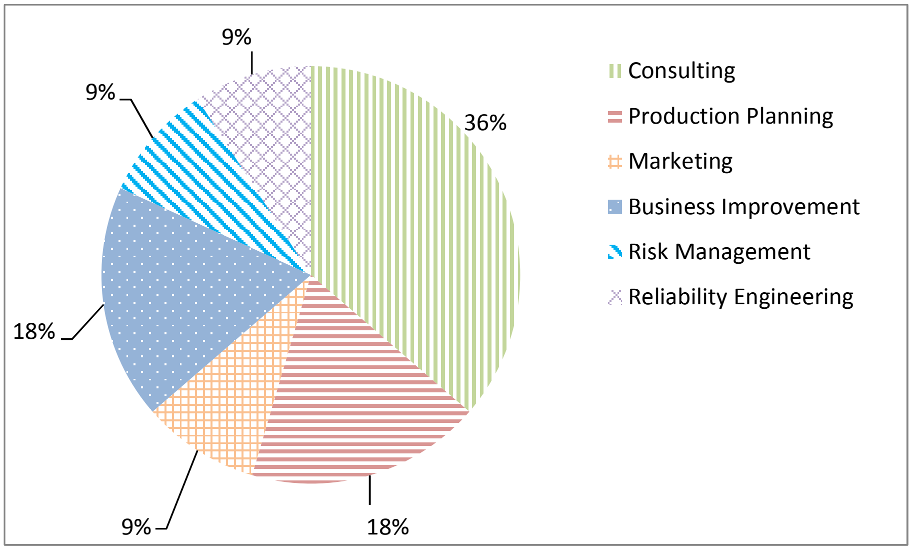


Figure 22 – Breakdown of "Others" selection as shown in Figure 21

The overwhelming majority of respondents work within a multinational corporation. This is evident in the fact that large capital investments are required to operate an MBP. It is usually large organisations that own and operate these facilities, and only in exceptional circumstances will a company have a smaller national footprint. Figure 23 shows information on the size of the organisations respondent's work for.

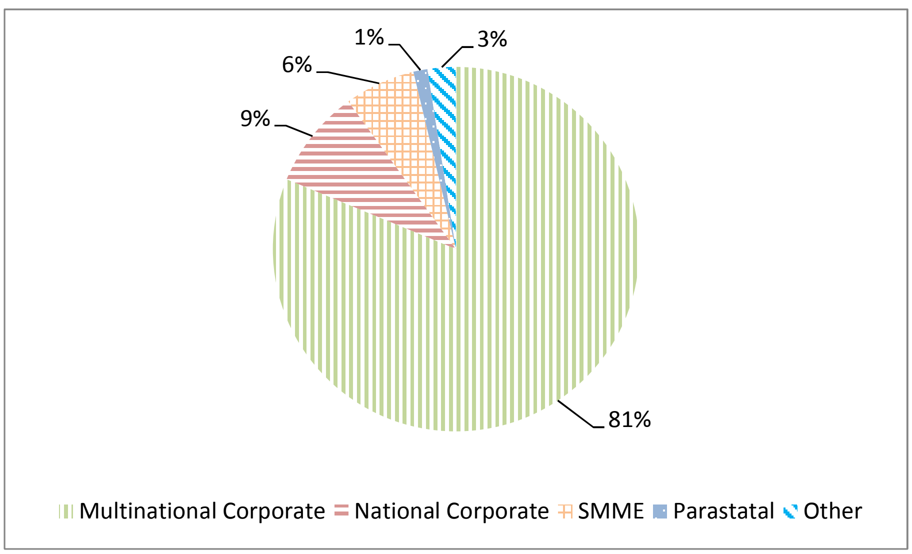


Figure 23 – The size of the organisation respondents are employed in

6.1.2 Knowledge of Established CI Theories

Respondents were asked to choose between different definitions for continuous improvement.

The definitions are given below:

Definition A: *Sustained Improvement targeting the elimination of waste in all systems and processes of an organisation.*

This definition specifically addresses continuous improvement from a Lean Manufacturing point of view. It purposely has elements of waste reduction in both systems and processes developed into the definition.

Definition B: *A gradual change of on-going improvements which aggregate over a period of time to provide visible proof that things are getting better.*

This definition indicates that continuous improvement is an aggregation of smaller improvements, over an undefined period of time, and not specifically large, intensive, once-off projects aimed at improvement of a specific process or system.

Definition C: *An organisation-wide process of focused and sustained incremental innovation.*

Innovation at an organisational level is the focus in this definition. This definition is typical of idea generation leading to change management in the form of new innovations.

Definition D: *A statistical approach of identifying bottlenecks in the organisation, which is then managed and improved through a projects approach.*

This definition is typical of the six sigma approach, where statistical methods are utilised to identify bottlenecks in the systems, after which a projects approach is used to address the deficiencies.

Figure 24 indicates the response from the survey with regards to the abovementioned definitions.

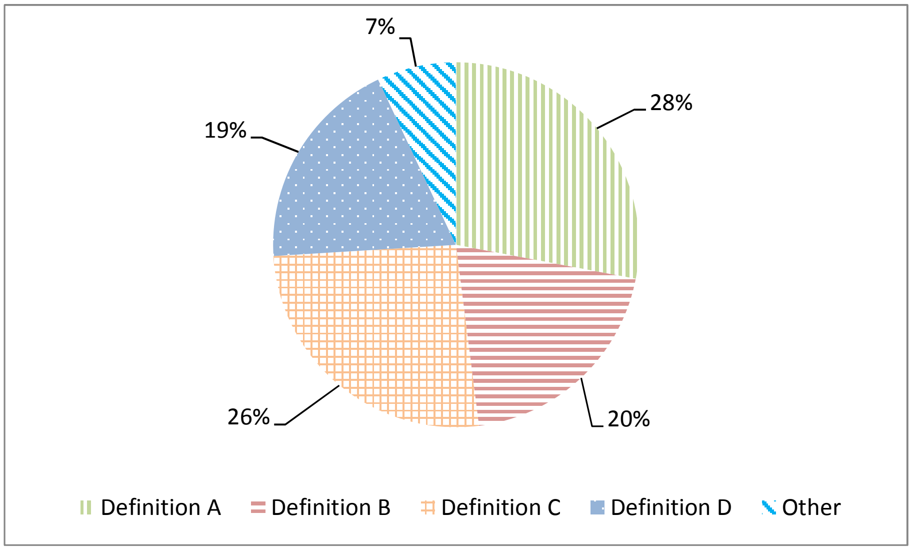


Figure 24 –Respondents' preference for the definition ofCI

The responses were fairly equally spread. From the results in Figure 24, it can be seen that the respondents have various views on how CI is defined. This could be explained by the fact that each definition alludes to one of the classical CI methodologies.

Respondents were requested to rate to what extent certain attributes are of importance in continuous improvement in the organization they work for. The following attributes were assessed:

- Quality of Production
- Throughput of Production
- Process Improvement
- New Technology Development
- Cost

- Efficiency Improvement

- Competitiveness

Figure 25 shows the average results to this question. Most respondents felt that Throughput of Production is the most important element in a CI strategy. This is followed by Cost and Efficiency Improvement.

The results are indicative of the business models prevalent in multinational corporations mining in South Africa. In a mining environment, throughput is hampered by the beneficiation processes following the mining activity. Added to that, if a smelter is part of the value chain, it is electricity constrained. Whichever way one looks at it, in the value chain of a mining company, MBP's are bottlenecks. The fact that cost and efficiency improvement is rated high also fits in well with the model described above. If for some reason throughput is low, MBP's need to produce at low cost and good efficiency to remain profitable.

Least important to the respondents were New Technology Development. Most major corporations have closed down its Research and Development (R&D) departments in cost cutting exercises. As such, due to the lack in research and technology development, respondents may view this as less important. Another reason may be that the processes involved in MBP's are well established, with few major leaps in process improvements. The scale used to rate the importance of these elements is shown in Table 5.

Table 5 – The scale used to determine importance of some attributes in the questionnaire.

1	Unimportant
2	Somewhat Important
3	Important
4	Very Important
5	Decidedly Important

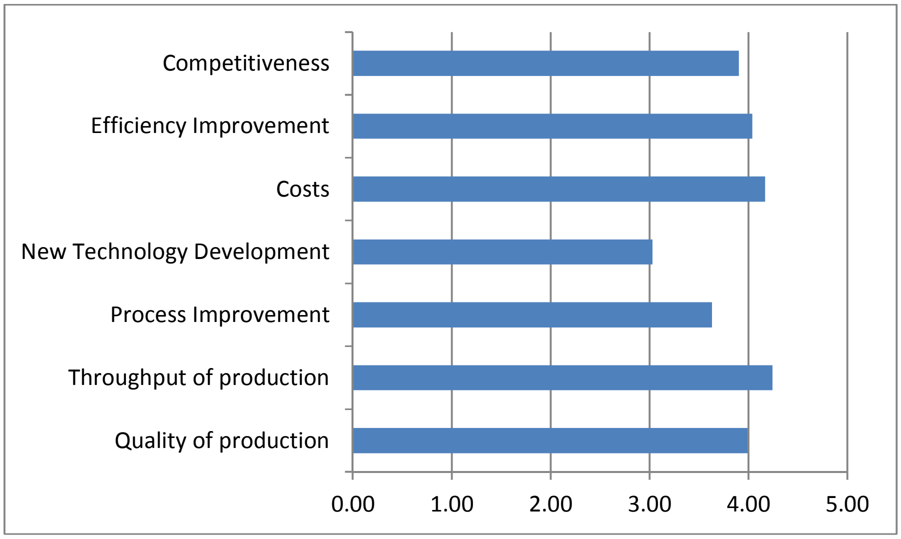


Figure 25 - Respondents view on importance of several elements of CI in their organisation

Figure 26 shows the respondents familiarity with some established CI theories.

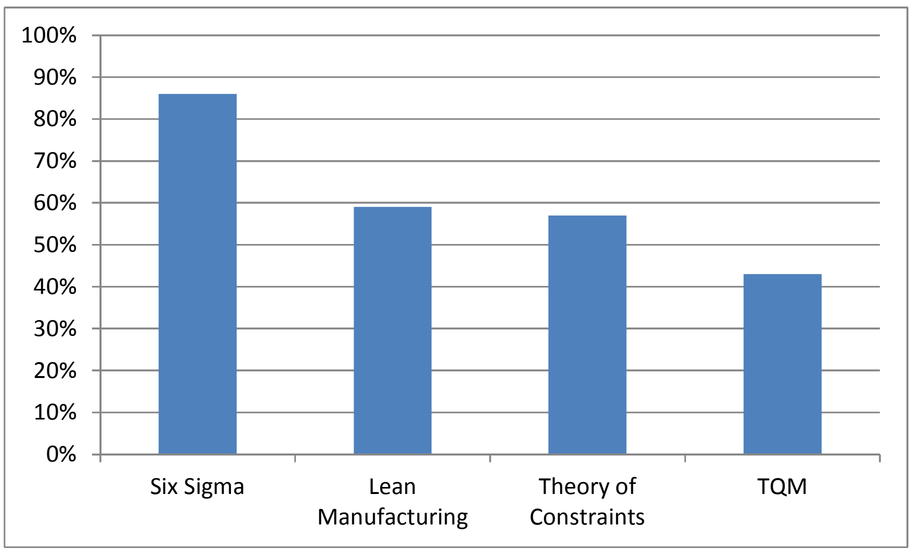


Figure 26 - Respondents familiarity with existing CI methodologies

Most respondents are familiar with Six Sigma, followed by Lean Manufacturing and Theory of Constraints. Less respondents were familiar with TQM. SS is atechnique that has been applied by various companies, and is quite common. It is known that BHP Billiton, Rio Tinto, Exxaro and Anglo American have utilised SS and/or LM in business improvement processes. This could explain the familiarity with this technique.

In order to understand the importance of certain CI strategies on the respondent's industry, the respondents were asked to rate the importance of CI Strategies on the industry they are employed in. Figure 27 shows the results from this question.

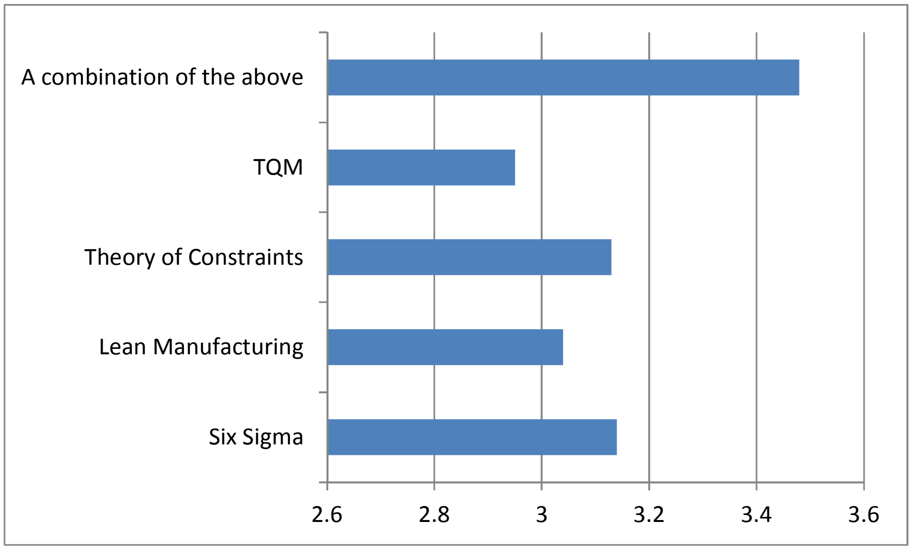


Figure 27 - The importance of CI methodologies within respondents' organisations

Most respondents felt that a combination of the CI strategies will fit in well with their organisation. This is a significant finding. It clearly shows that respondents agree that no singular technique could be successfully applied to an MBP. What is interesting to note is that TOC is considered more applicable to MBP's than LM. Again, this may relate to the focus within MBP's to increase throughput, and hence increase total throughput capacity, as MBP's are bottlenecks in the value chain of mining companies.

6.1.3 Theory of Constraints

In order to understand the respondents' comprehension of Theory of Constraints, various questions related to TOC were asked. Respondents were questioned on what definition fits TOC best. The definitions are given below:

Definition A: *A management approach which focuses on improving bottleneck processes, to continuously improve the performance of manufacturing operations.*

The definition specifically states that TOC is a way to manage the organisation. It therefore immediately alludes to strategic direction set, with a top-down approach. The focus is on bottleneck or "under-utilised" processes.

Definition B: *A body of knowledge about systems and the interaction of their component parts which rely on five focussing steps (Identify, Exploit, Subordinate, Elevate, Repeat & Prevent Inertia) to guide the system improvement efforts.*

The focus is here more on systems than processes. It also specifically mentions the five focussing steps that need to be followed in order to improve these systems.

Definition C: *A method to pin point underperforming areas in the manufacturing process, and improving it.*

This definition specifically states a manufacturing process, and related underperforming area thereof.

Definition D: *A structured method to identify the weakest link in the production chain, followed by the maximum utilisation of the bottleneck asset*.

In this definition, TOC is described as a structured method, aimed at identifying a poor performing area in a production chain. It also specifically mentions utilisation of assets.

Figure 28 shows that definition A, B and D to be favoured by the respondents. Definition C was less favoured, showing only 13%. From this result, it can be said that respondents do not feel that TOC can only be limited to an approach to identify and improve underperforming areas in a manufacturing process.

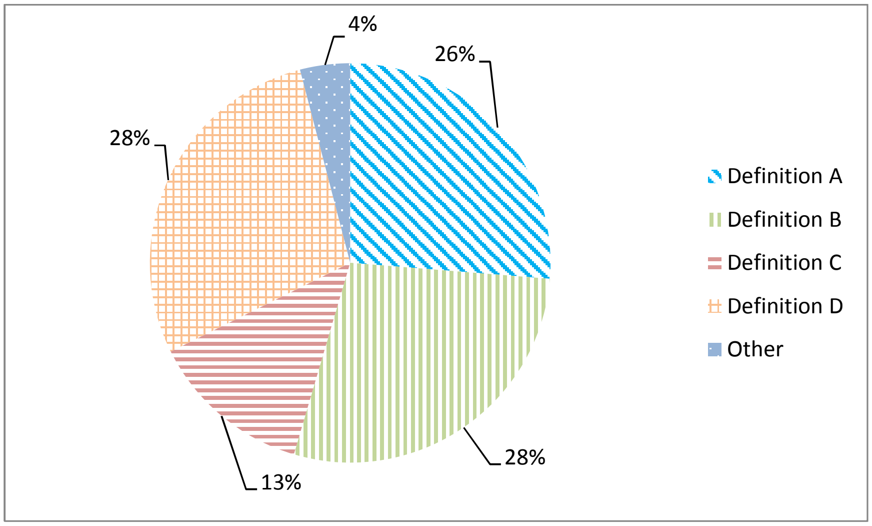


Figure 28 - Respondents' preference for the definition of TOC

Throughput of Production is perceived by most respondents (53%) to be the main driver of TOC. Secondary drivers seem to be Process Improvement (18%) and Quality of Production (11%). This is in line with the respondent's perceived definition of TOC, which was of an improvement in processes and systems, specifically addressing the maximum utilisation of the bottleneck area. The result of this will lead to an increase in throughput of either the system as a whole or the processes within. This result is shown in Figure 29.

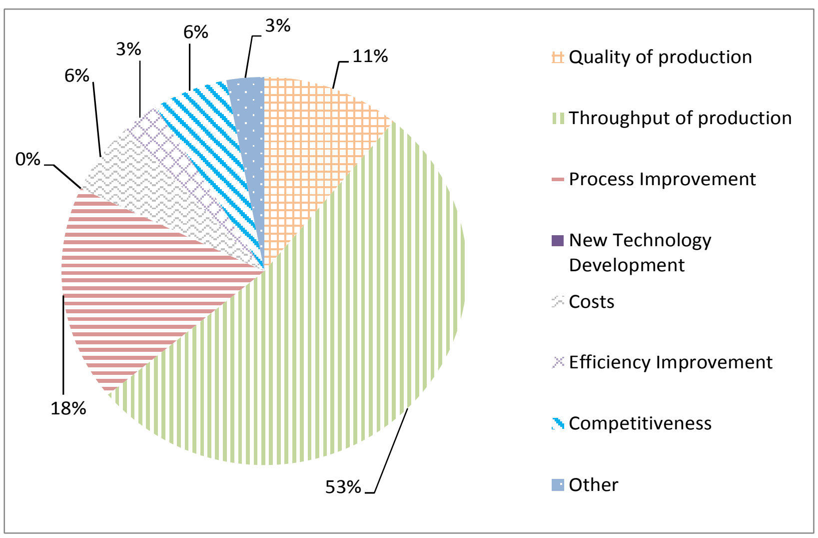


Figure 29 - Respondents' view on the main drivers of TOC

From the survey results it emerged that 40% of respondents have been involved in CI initiatives utilising TOC.

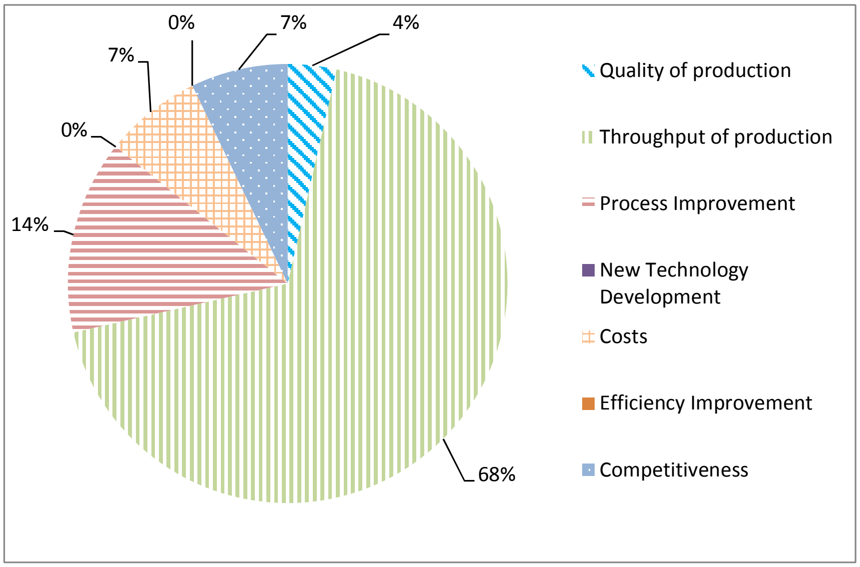


Figure 30 - Respondents whom have utilised TOC, views this as the driver behind utilising TOC as improvement initiative

Throughput of production was the main driver of TOC according to the respondents whom have used TOC as improvement initiative. This accounted to 68% of respondents. Process improvement seems to have been a driver to some respondents, with 14 % stating this to be the main driver of utilising TOC. None of the respondents utilised TOC for develop new technology. These results are shown in Figure 30.

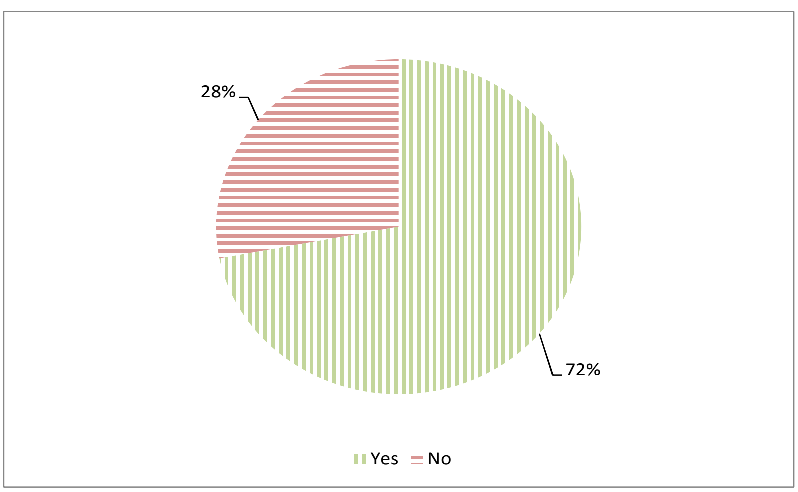


Figure 31 - The success rate of TOC as judged by respondents whom have used TOC in the past

More than a quarter of respondents stated that TOC was not successful in addressing specific challenges in the improvement environment. This is shown in Figure 31. Since TOC was utilised to improve throughput of production, it can be seen that it is mostly used to improve processes. The potential it has to improve the system as a whole, and hence improve competitiveness seems to be overlooked. It is also seen that inherently TOC does not lend itself to improvement in costs and quality. The results in Figures 30 and 31 clearly shows that TOC could be applied to improve throughput, which was identified as a major focus area for the respondents. There lies value in developing a model which incorporates the principles of TOC for specifically throughput improvement.

6.1.4 Six Sigma

In order to understand the respondents comprehension of Six Sigma, various questions related to Six Sigma were asked. Respondents were questioned on what definition fits Six Sigma best. The definitions are given below:

Definition A: *An organised and systematic method for strategic process improvement and new product and service development, that relies on statistical methods and the scientific method to make dramatic reductions in customer defined defect rates.*

This definition states that SS is a strategic approach, targeting three areas: Process Improvement, New Product/Service Development and Quality. This is achieved by reducing defect rates. This definition also relates to the role the customer plays in the organisation. It specifically notes the role statistical analysis play in solving problems.

Definition B: *Management approach which is project-driven, to improve the organisation's products, services, and process by continually reducing defects in the organisation.*

The role management plays is highlighted in this definition. It specifically states that SS is a project driven approach aiming at improvement of the organisation, by reducing defects.

Definition C: *Business process that allows companies to drastically improve their bottom line by designing and monitoring everyday business activities in ways that minimise waste and resources while increasing customer satisfaction by some of its proponents.*

This definition is based on an improvement in costs, and is defined as an overarching business process aimed at minimisation of waste and resources whilst alluding to customer satisfaction

Definition D: *An organised, parallel-meso structure to reduce variation in organisational processes by using improvement specialists, a structured method, and performance metrics with the aim of achieving strategic objectives*.

In this definition, a parallel organisational structure is proposed. This means that the improvement specialists work outside of the line function, in a structured method to achieve strategic objectives.

Figure 32 shows that definition A is favoured by the respondents. It can be stated that most respondents (42%) feel that Six Sigma is a statistical and structured method that delivers process improvement and new product development through an improvement in quality. This is in line with the broad spectrum training on SS, which specifically focuses on analysing problems statistically. Definition C and D were least favoured, showing only 17%. It is surprising that Option D is not favoured by more respondents, as the main stream SS specialists insist on having BI practitioners outside of the line function.

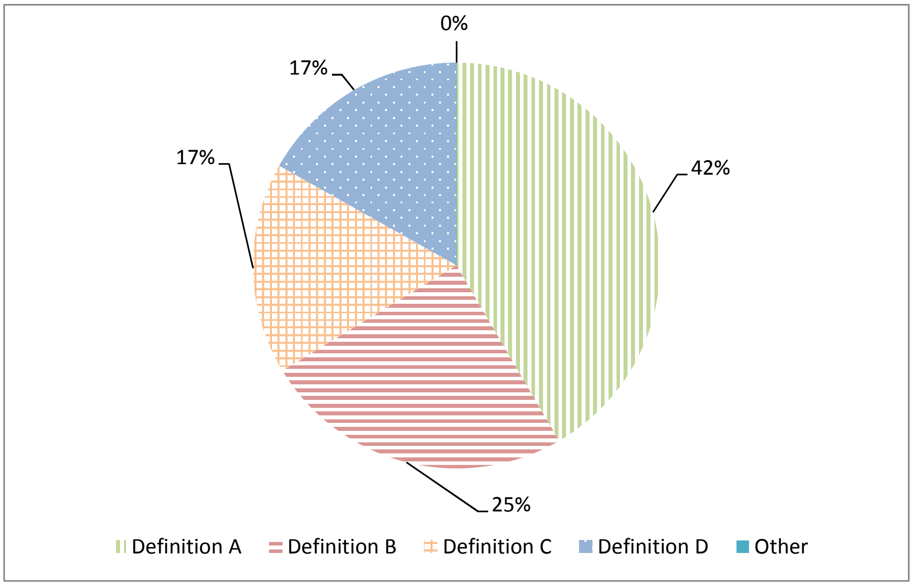


Figure 32 - Respondents' preference for the definition of SS

Process Improvement is perceived by most respondents (34%) to be the main driver of Six Sigma. Secondary drivers seem to be Quality of Production (28%) and Efficiency Improvement (18%). New Technology Development and improvement in costs are not perceived to be drivers of SS. This is shown in Figure 33.

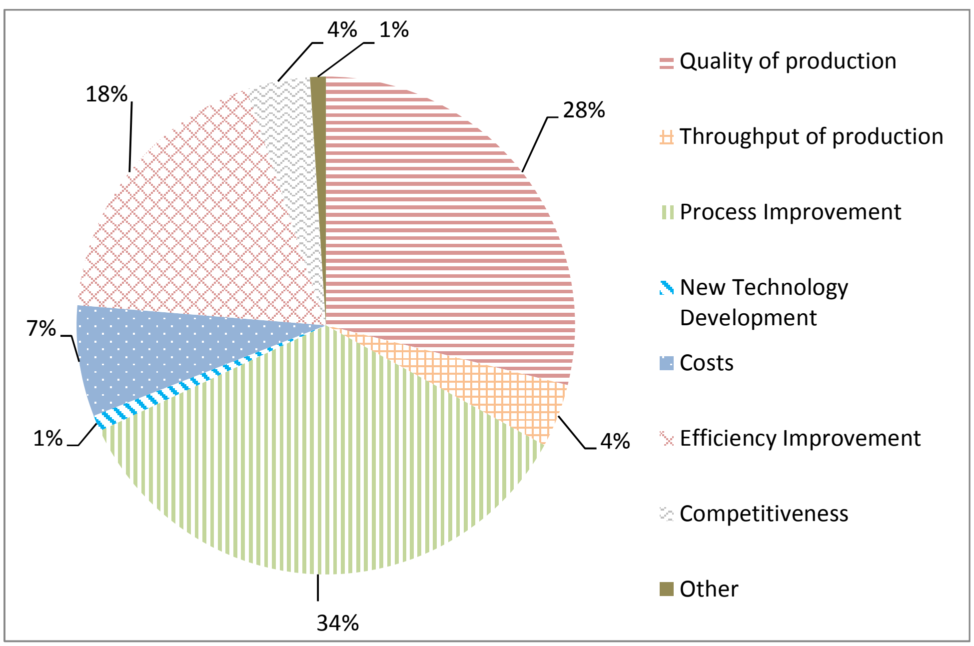


Figure 33 - Respondents' view on the main drivers of SS

It is seen that 64% of respondents have been involved in CI initiatives utilising Six Sigma. Of the 64% who has experience in Six Sigma, 27% stated that the aim of Six Sigma was to improve processes. An equal amount of respondents stated that Quality of Production is the main driver of Six Sigma.

Some respondents utilised SS to improve efficiencies (18%) and throughput of production (11%). There are respondents that used SS for lowering of costs (9%) and developing new technology (7%).

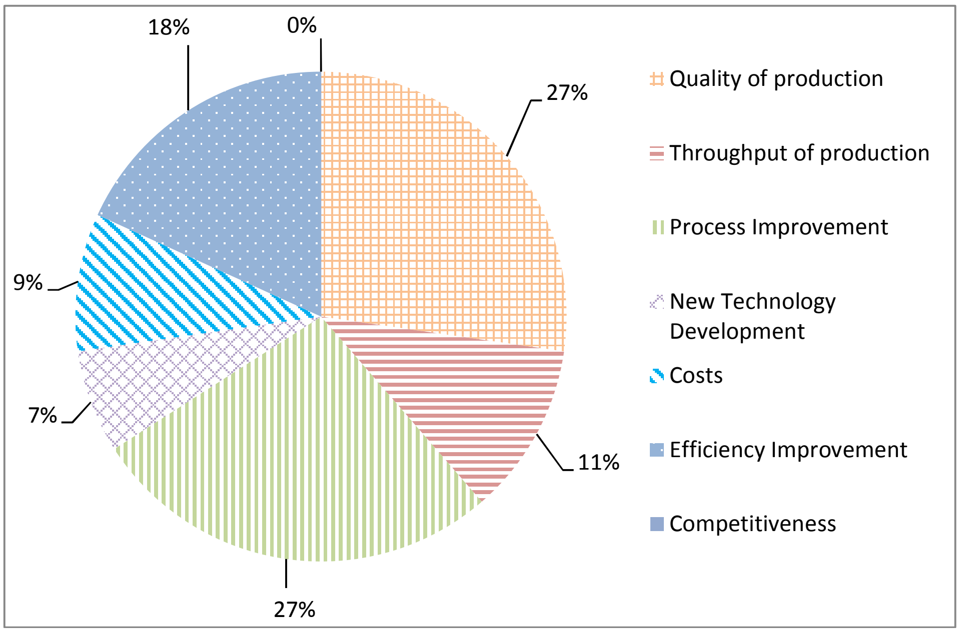


Figure 34 - Respondents whom have utilised SS, views this as the driver behind utilising SS as improvement initiative

None of the respondents utilised Six Sigma for improved competitiveness. The results are shown in Figure 34.

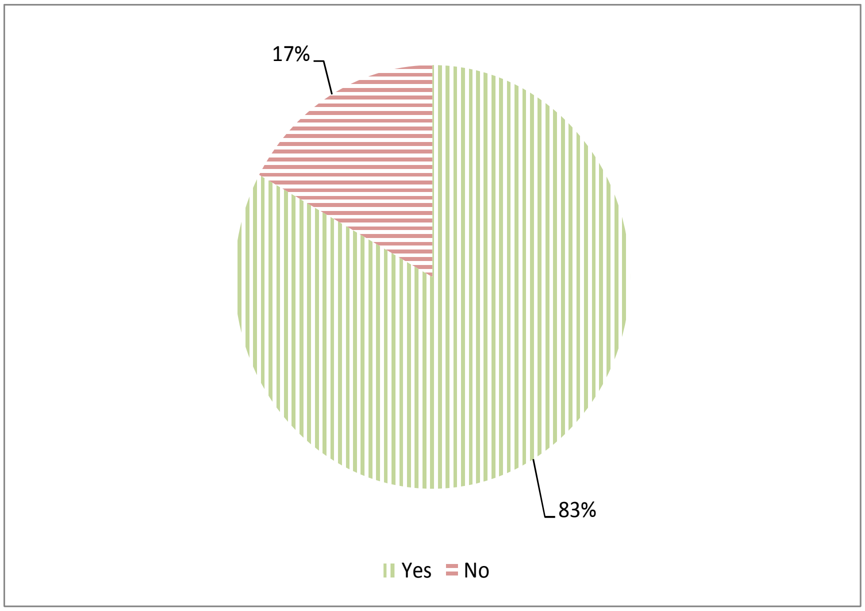


Figure 35 - The success rate of SS as judged by respondents whom have used SS in the past

A large number of respondents (83%) who have used Six Sigma in improvement initiatives, felt that it adequately addressed specific challenges in the improvement environment. The great success rate is indicative of SS approach in measuring and improving process variables. It is clear that SS could easily be incorporates into a model for an MBP, as the applicability to an MBP seems to be rife. This is shown in Figure 35.

6.1.5 Lean Manufacturing

In order to understand the respondents comprehension of Lean Manufacturing, various questions related to Lean Manufacturing were asked. Respondents were questioned on what definition fits Lean Manufacturing best. The definitions are given below:

Definition A: *A strategy aiming for the ceaseless elimination of waste.*

This definition states that LM is a strategy to eliminate waste. The waste referred to in this definition is not necessarily confined to physical waste.

Definition B: *A philosophy of achieving improvements in the most economical ways with special focus on reducing waste.*

This definition states that LM is a philosophy, i.e. a way of living and/or thinking, achieving improvements at low cost, with emphasis on waste reduction.

.

Definition C: *A pull model (customer needs) that focuses on a reduction of over production.*

This definition specifically addresses the customer's needs to ensure that production only focuses on the market requirements, and nothing more.

Definition D: *A structured approach with various techniques focussing on the improvement of the 4 M's - Man, Machine, Method and Materials.*

This definition is vague in how LM achieves improvement, but it does focus on where improvement is achieved.

Figure 36 shows that definition A is favoured by the respondents. This is in line with the thought process that LM is a strategic approach focussing only on the elements in the business that matters, and eliminating the wasteful processes and systems in the business. Definition C was least favoured, showing only 10%. This is probably due to the fact that MBP's are bottlenecks in the mining value chain, and as such would not be easily faced with a situation of over production. However, since any product produced by an MBP has a customer, it is certainly still relevant to consider the customer's expectation.

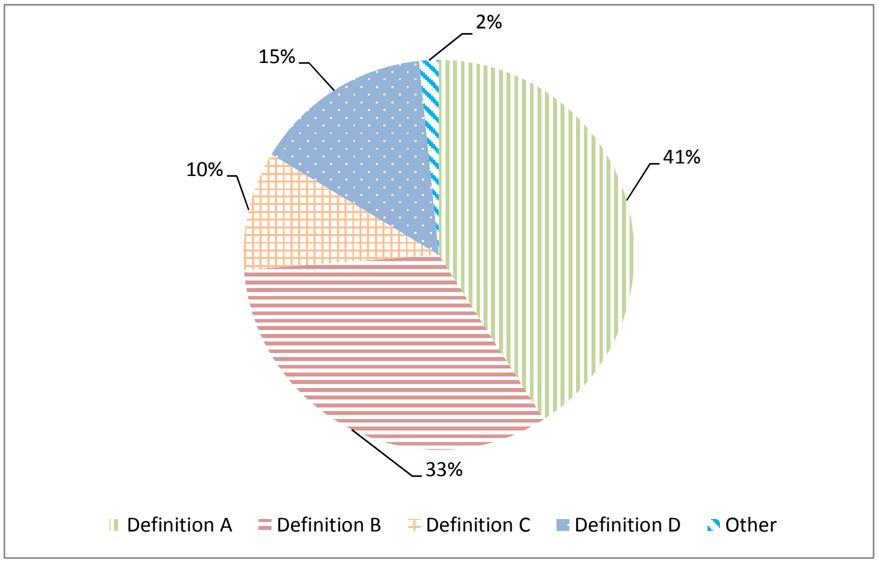


Figure 36 - Respondents' preference for the definition of LM

Efficiency Improvement is perceived by most respondents (34%) to be the main driver of Lean Manufacturing. Efficiency in its simplest form, is a term describing the most productive scenario available, and hence subscribes to the philosophy of waste reduction. The survey showed that secondary drivers seem to be Costs (24%), Process Improvement (13%) and Quality of Production (10%). This is shown in Figure 37.

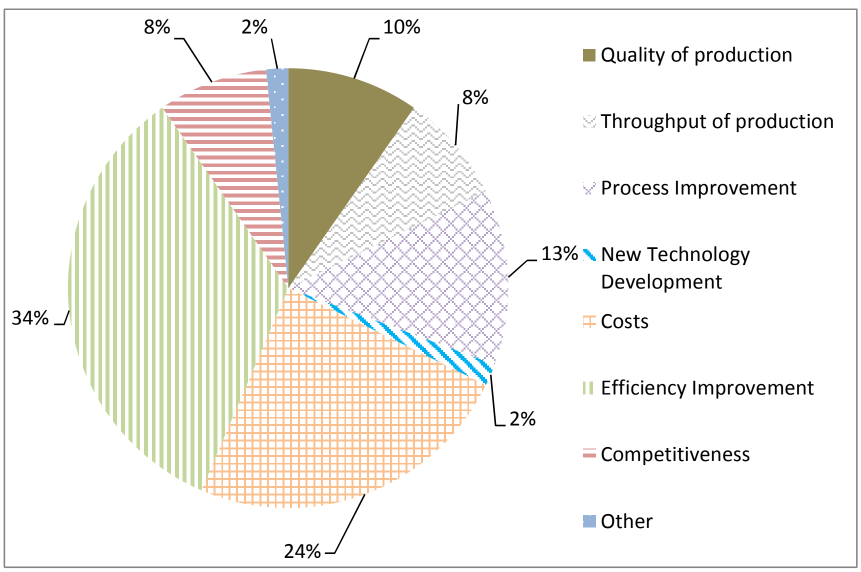


Figure 37 - Respondents' view on the main drivers of LM

It is seen that 44% of respondents have been involved in CI initiatives utilising Lean Manufacturing. Of the 44% who has experience in Lean Manufacturing, 39% stated that the aim of Lean Manufacturing was to improve efficiency. Costs were the main driver of about 29% of respondents whom have used Lean Manufacturing before. None of the respondents utilised Lean Manufacturing for New Product Development.

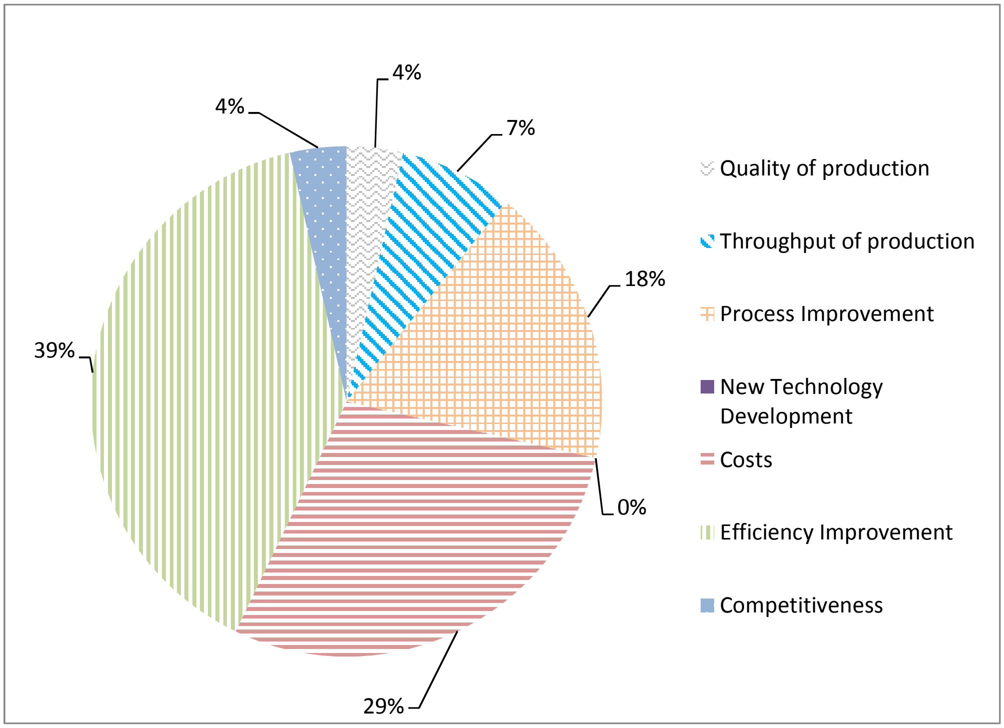


Figure 38 - Respondents whom have utilised LM, views this as the driver behind utilising LM as improvement initiative

Process Improvement were seen by 18% of respondents as the main driver of Lean Manufacturing. The results are shown in Figure 38.

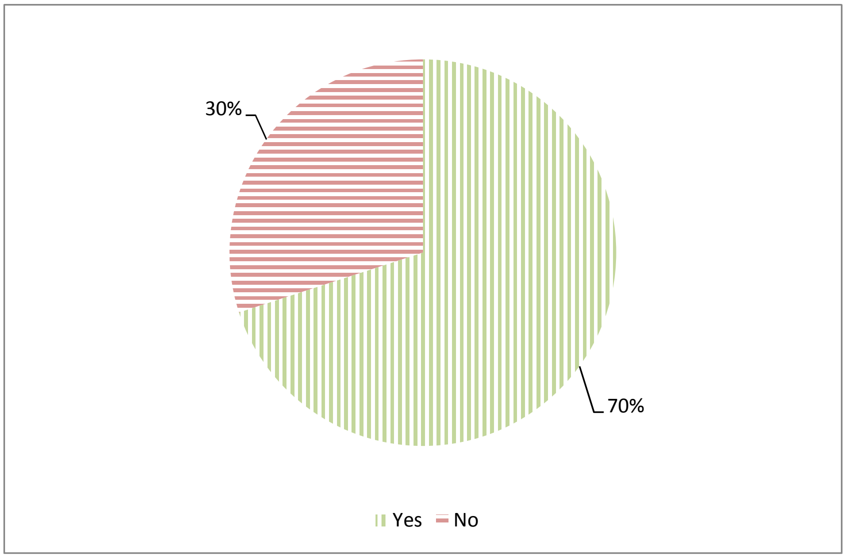


Figure 39 - The success rate of LM as judged by respondents whom have used LM in the past

Less than a third of respondents (30%) did not have success with Lean Manufacturing as an improvement tool. From these results, it can be assumed that LM could be utilised in a combined model as well, since as an individual improvement initiative it has proven to be successful. This is shown in Figure 39.

6.1.6 New Model Development

In order to understand the requirements for a universal CI model that can be applied to any MBP, the respondents were questioned on various aspects related to a combined model.

According to the respondents, the five most important elements that should be present in a CI Strategy are as follows (Figure 40):

1. Efficiency Improvement

2. Process Improvement

3. Cost Reduction

4. Waste Reduction

5. Quality Management

It is important to understand why respondents are of the opinion that the abovementioned aspects are critical in the development of a CI model for an MBP.

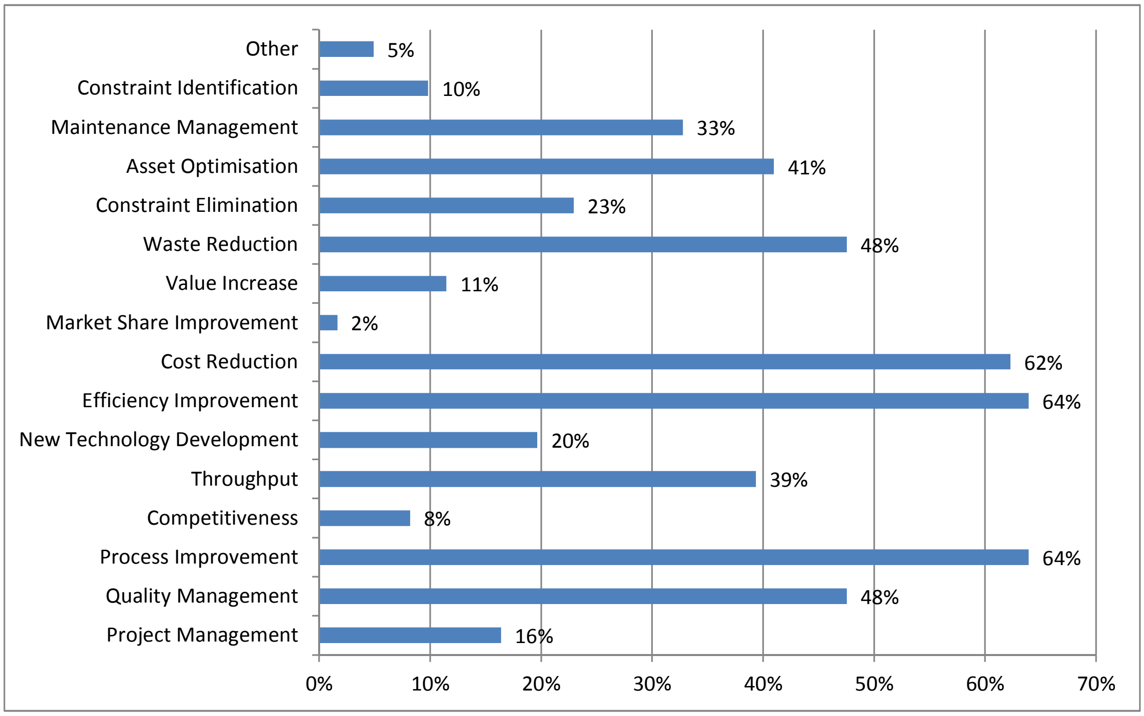


Figure 40 - Respondents view on the 5 most important elements that should be present in the ideal CI model for a MBP

In response to the question posed, whether a minerals process plant could benefit from an active continuous improvement programme, 98% of respondents answered yes (Figure 41).

Respondents had various different personal opinions on why they feel an MBP will benefit from a CI programme. By using coding techniques (Boeije, 2010:94-121), various themes were identified by interpretation of the answers given by the respondents.

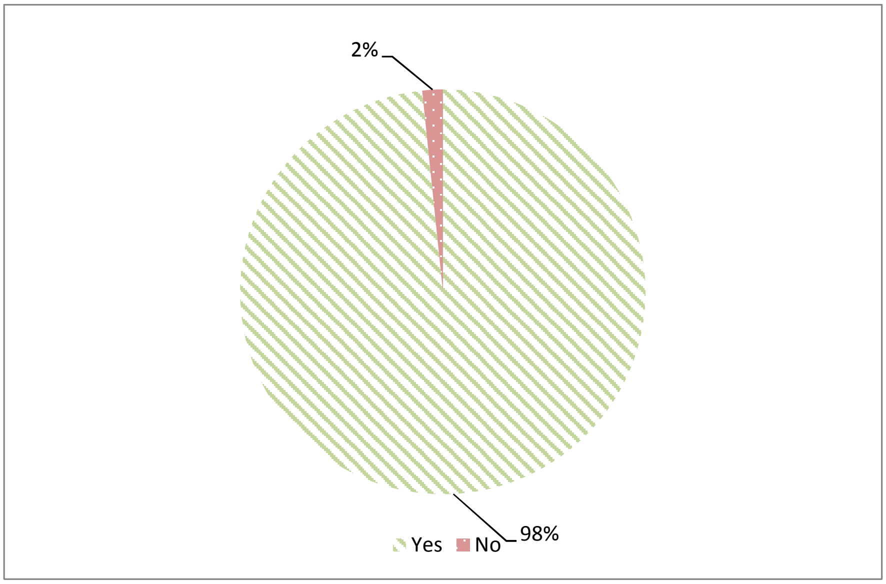


Figure 41 - Respondents view on whether a MBP could benefit from having an active CI programme in place

Figure 42 shows the category or elements which were identified through the explanations given on why respondents feel that an MBP should benefit from an active CI Programme. The results are very much in line with the results obtained in Figure 40. It is clear that cost reduction is one of the main categories that will benefit from a CI Programme. Some of the explanations by the respondents are given below:

"…because in any process plant costs (especially fixed costs) will always increase, and CI is imperative to minimize these costs, in order for a production plant to stay in business."

"A Project that is executed should increase your production or lower the Rand per ton of metal. This will make you more competitive. This becomes more and more important as rising economies such as India and China try to grab market share."

Improvement in the process as well as efficiency of the system is also deemed important benefits of a CI Programme. Some of the comments by respondents are as follows:

"Using a CI programme one can always improve throughput, improve efficiencies and improve quality of production which are essential to competitiveness."

"By continuously reassessing the entire process in order to identify inefficiency and improve on identified areas will definitely benefit the process plant. This is mainly because you continuously identify room for improvement."

Competitiveness of the business was identified as a possible benefit. This was however not seen as an important element to be part of a CI Programme. Only 8% of respondents felt it necessary to specifically include this in the ideal CI Programme (see Figure 40). One may draw the conclusion that a higher level of competitiveness is a result of an active CI Programme. Some of the answers relating to competitiveness are given below:

"If you don't improve your competitors will improve and you will stay behind."

"(Continuous Improvement) makes the plant to be competitive and succeed in driving the costs down and (people) working smarter."

"Change and improvement should be the only constant. (In order) to stay competitive, this need not be drastic e.g. Technology may be explored to ensure operational effectiveness at a value adding cost/benefit."

Constraint identification and elimination were mentioned seven and four times respectively. These categories go hand in hand, as identification of constraints is worthless if the follow-up step of elimination is not followed. Some of the comments related to this are as follows:

"It allows a high-level view of the inefficiencies in the process and assists in: 1) closing any performance gaps identified; and 2) taking the plant's performance to a higher level"

"An Active CI programme will have benefits, because the gap(s) can always be identified in the process and it can be eliminated."

Some respondents had a very holistic view of a CI Programme. They touched on most categories identified. These are typical examples:

"With time, new challenges arrive in any kind of manufacturing or design related facility. The fundamental understanding of the basic processing is of course necessary but more often than not, this information is not always sufficient to deal with problems that might come on hand in the future. Dealing with real problems needs a hands-on and continuous evaluation approach to ensure that problems are addressed correctly and that an effective (whether it be environmental, cost or market share related) solution is found."

"In my experience, only the aspects of a plant that are monitored carefully are focusedon.Without a proper programme in place to monitor and guide the process, improvement projects typically tend to yield little results."

"If you continue the way you are now, you will eventually fall behind, as other plants will improve. New technology/materials/methods are always available that will help bring down cost and improve throughput. When these options are exploited the goals are more easily achieved, which results in higher profits/margins."

A couple of additional concepts were identified as well. This was grouped in the larger category listing in Figure 43.Respondents oftenreferred to sustainability.
It was however identified as a concept which will be the result of success in the "Competitiveness" category. Some of the responses are given below:

"Without a programme to drive continuous improvement, improvement efforts are often misaligned, conflicting, suck resources (too many operating at once) nor are sustainable (which is the most important part). Furthermore, large companies often jump to spending capital on plant improvements without first exhausting all other options (including a continuous improvement programme)."

"In a commodity business environment the lowest cost producer ensures sustainability and continuous existence."

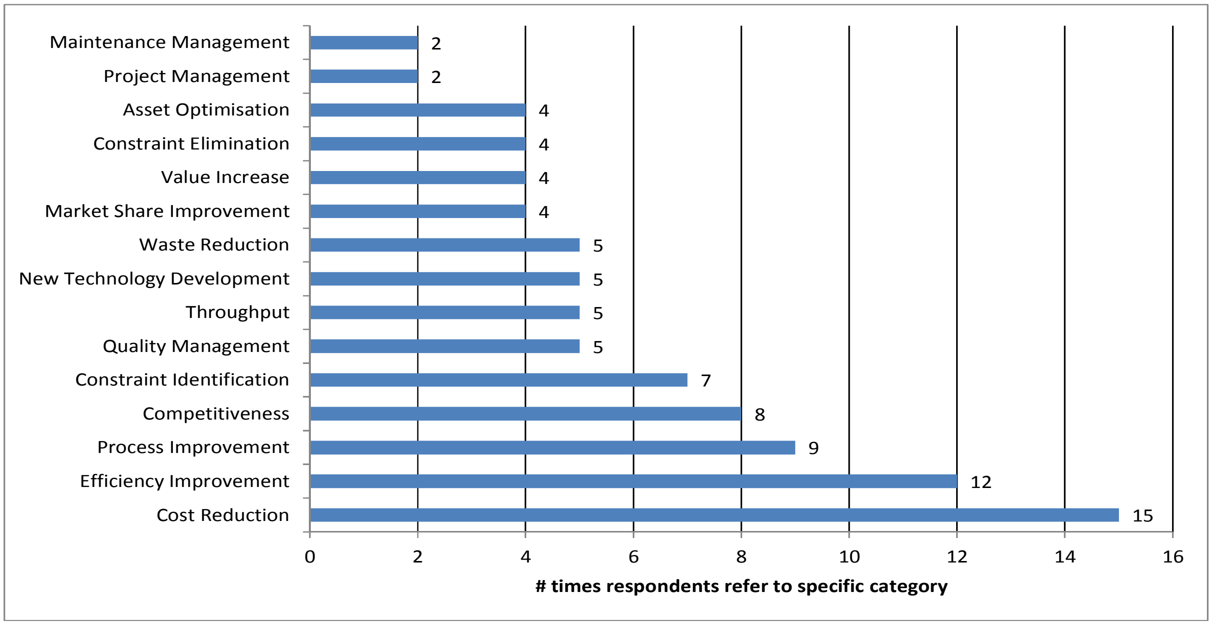


Figure 42 - Categories/Elements identified by analysing the qualitative answers given by respondents on why it is important for an MBP to have an active CI Programme

The concept of growth was mentioned by some respondents. This was defined as an outcome of the "Market Share Improvement" category. Some of the responses are listed below:

"A Continuous Improvement Programme leads to a) prevention of stagnation of thinking. Keep up with best practices."

Several of the respondents alluded to the important cultural changes that can result from a CI Programme:

"There is significant value potential in and a great business case for sustained continuous improvement, because the cost is minimal (and often covered in existing job descriptions) and the cumulative pay-off over time (including culture change) is significant."

"…CI should be part of any technical, process and management staff member's working life - it is in my view the only way to see sustainable improvement of any form on any process plant."

The concept of innovation, and its importance as a driver for New Technology Development was mentioned by some respondents:

"There is increased focus on incremental improvements as a discipline which results in a culture of innovation."

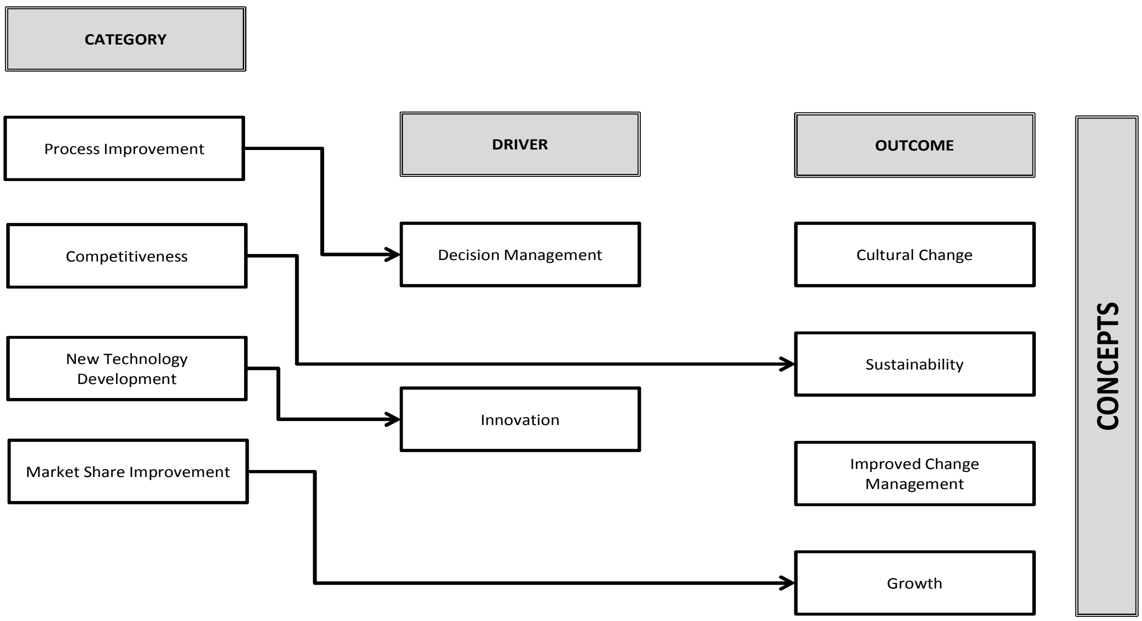


Figure 43 - Additional concepts identified and classified according to the major categories defined

Another driver identified by respondents for Process Improvement was an improved decision management culture, especially for the shop floor employee:

"In continuous operations operators tend to limit their thinking within the boundaries of what has worked for them in the past … A continuous improvement program will force operators to continually question what is being done, thereby allowing them to think out of the box."

With these results in mind, the respondents were questioned on the higher level management scope of a CI Programme. The results are shown in Figure 44.

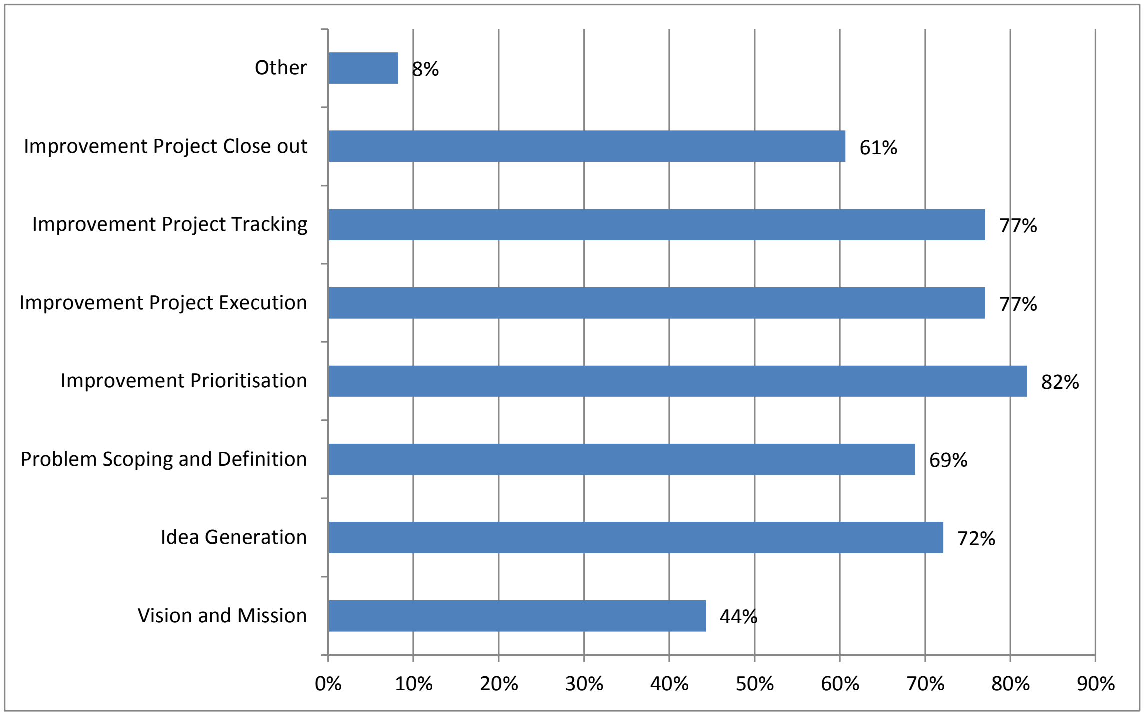


Figure 44 - Respondents view on the typical elements that would form part of a CI Programme

From Figure 44 it can be seen that the following five elements are of importance in the scope of a CI programme:

- Problem Scoping and Definition (69%)
- Idea Generation (72%)
- Improvement Prioritisation (82%)
- Improvement Project Execution (77%)
- Improvement Project Tracking (77%)

It is interesting to note that only 44% of the respondents feel that the vision and mission of an organisation is not important to the CI strategy of an MBP. It must be noted though that any important strategy should be underpinned by the vision and mission of a company, as failure would be imminent if not part of the executive plan.

Chapter 7

"There's a way to do it better – find it!"

Thomas Edison

7.1 Continuous Improvement Model for a South African Minerals Beneficiation Plant

From the results it is clear that respondents felt that indeed a CI programme would be beneficial to a MBP. It is also seen that elements of each of the established programmes can be utilised, but that respondents feel a combination of the three established theories will be the most suitable model for a MBP. In the development of this model, one therefore has to determine which elements would be advantageous if utilised in a MBP, and which would classically fall within the category of force fitting.

7.1.1 Developing Strategy – Phase 1

Before any CI programme can be implemented, it has to be approved and endorsed on an executive level with clear strategic intention. Kourdi (2009:3) states, that a business strategy is the plans, choices and decision that guide a company to greater profitability and success, and also provides a guiding view of the future that will sway decisions, priorities and ways of working. In order for any CI programme to succeed, it will have to be part and parcel of the strategy of a company. The strategy will set the direction, and focus employees' decision making skills on improvement at all levels. However, each strategy needs to be formed and moulded from the vision of the organisation.

Collis & Montgomery (in Furrer 2011:2-3) proposes a framework that includes all different elements and activities that fall under the scope of corporate level strategy. This framework can be seen in Figure 45.

The five elements presented are as follows:

- vision, goals and objectives
- resources
- businesses
- the role of corporate office, including its structures, systems and processes
- corporate advantage

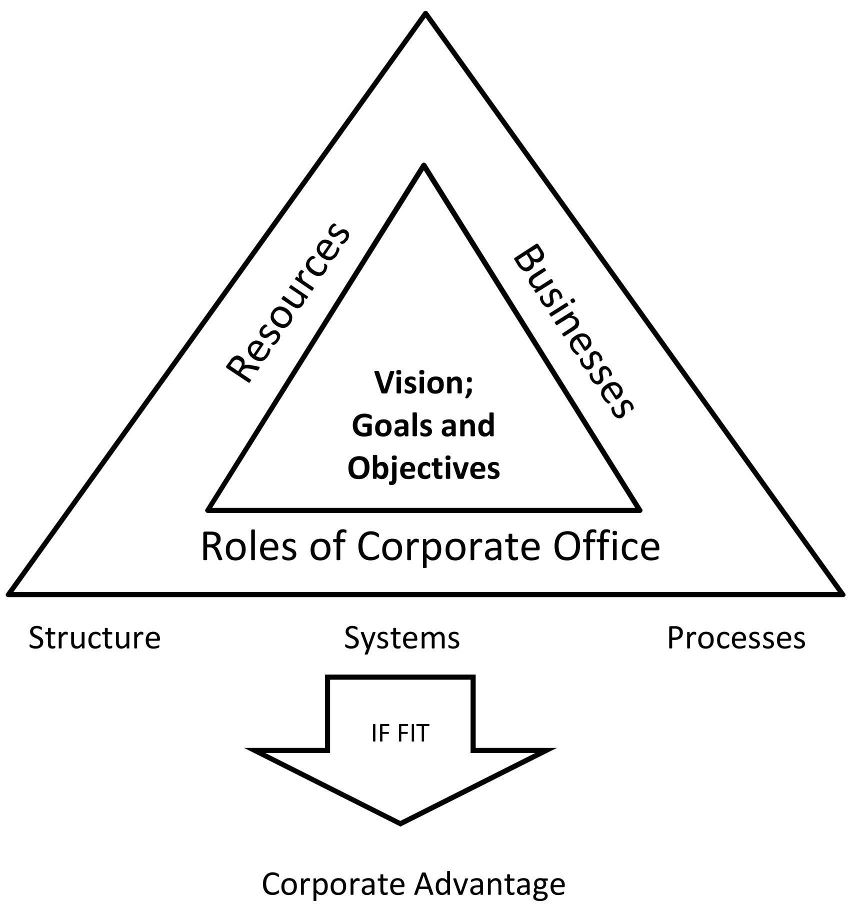


Figure 45 – Collis and Montgomery's corporate strategy framework (Furrer:2011)

Kourdi (2009:103) states that if a business has a clear vision to which it aspires, it will contribute in engagement of employees and unlock energy and commitment.

The vision defines the company's domain of activities (Furrer 2011), and is essential in establishing the strategy of the company.

From the vision one can now align goals and objectives. Resources, whether human or technological, can be assigned to execute the plans associated with the strategy. These resources need to utilise the appropriate systems and processes. According to Mr Chris Jordaan (2012), Chief Executive Officer (CEO) of International Ferro Metals (IFM), all resources, need to be assigned and utilised in the correct structure. This is echoed by Furrer (2011:3), stating that identification, building and deployment of these resources are critical aspects of strategy.

In order to fulfil the required vision, goals and objectives are crucial (Furrer 2011:3).These goals and objectives can be seen as Key Performance Indicators (KPI's) that guide the resources in delivering on the strategy. In conjunction with KPI's, a business also needs to identify its Key Value Drivers (KVD's).

The KVD's are measurements of the facets of a business process that has a profound effect on the results thereof. It has a substantial value impact, and are elements that are in control of the operation team.

The first portion of the CI model is the strategic intent. This strategic intent is the foundation of any CI programme at an MBP. The strategic intent is shown in Figure 46.

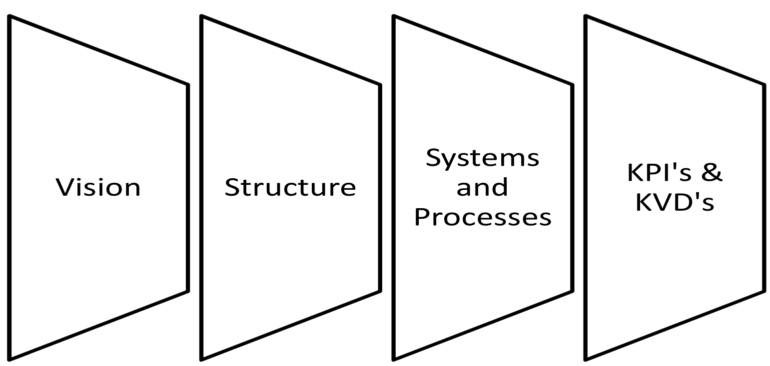


Figure 46 – Strategic intent of the CI model.

The first element in this model is the development of a vision. The vision of the business should include a clear intention to continually improve in all aspect and levels of the business. As stated above, this forms the starting point of the strategy of the business, which will feed into the CI model. The strategic decision to support CI within the business should be at the executive level, and should be supported and encouraged in a top-down approach.

Developing the correct structure for the organisation is an essential part of the process. According to Smit et al (2011: 216) employees can only work effectively towards the vision, mission and goals of an organisation, if a proper structure is organised and defined.

In an organisation where CI is a visionary necessity, it is of cardinal importance that tasks necessary to achieve CI goals, are assigned to the right team, but more importantly, to develop a structure that ensures good co-ordination between departments (Smit et al, 2011:217). In a typical structure on an MBP one would find three distinct work cycles. This is shown in Figure 47.

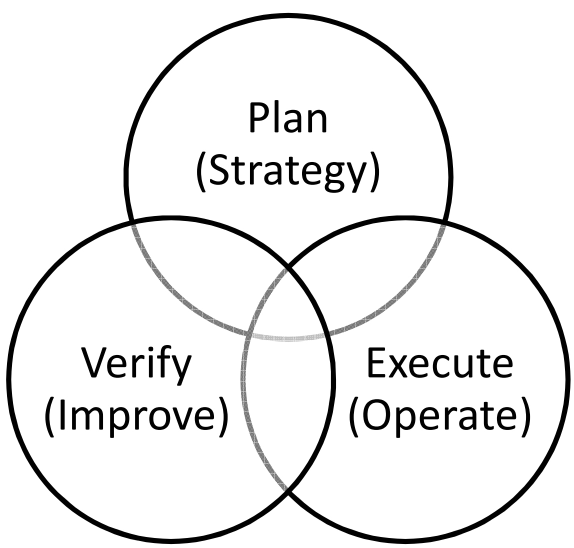


Figure 47 – Different work cycles in a typical MBP

Improvement is seen as a distinctly different work cycle than Production. In order for any CI model to be functional, it is important to differentiate between the execution team, and the improvement team. It is very difficult for any individual or team to work in more than one work cycle.

A functional structure would be ideal in this situation, one that dictates a definitive role for an improvement specialist or team. In this case, the improvement team will have the responsibility of facilitating the process of improvement, but execution of improvement initiatives still lies within the work cycle of the Execution Team.

A proposed structure for a MBP is shown in Figure 48. This structure proposes a dedicated manager to lead the improvement department. The reason for this is to fulfil the third work cycle of verification of improvement. The improvement manager will have functional heads specialising in improvement reporting into his/her structure. Operational departments, such as Production and Maintenance shall be supported by an improvement specialist with expertise in the specific functional field. Typically these positions will be filled by engineers or CI practitioners, with theoretical and practical knowledge of the specific processes within a functional system.

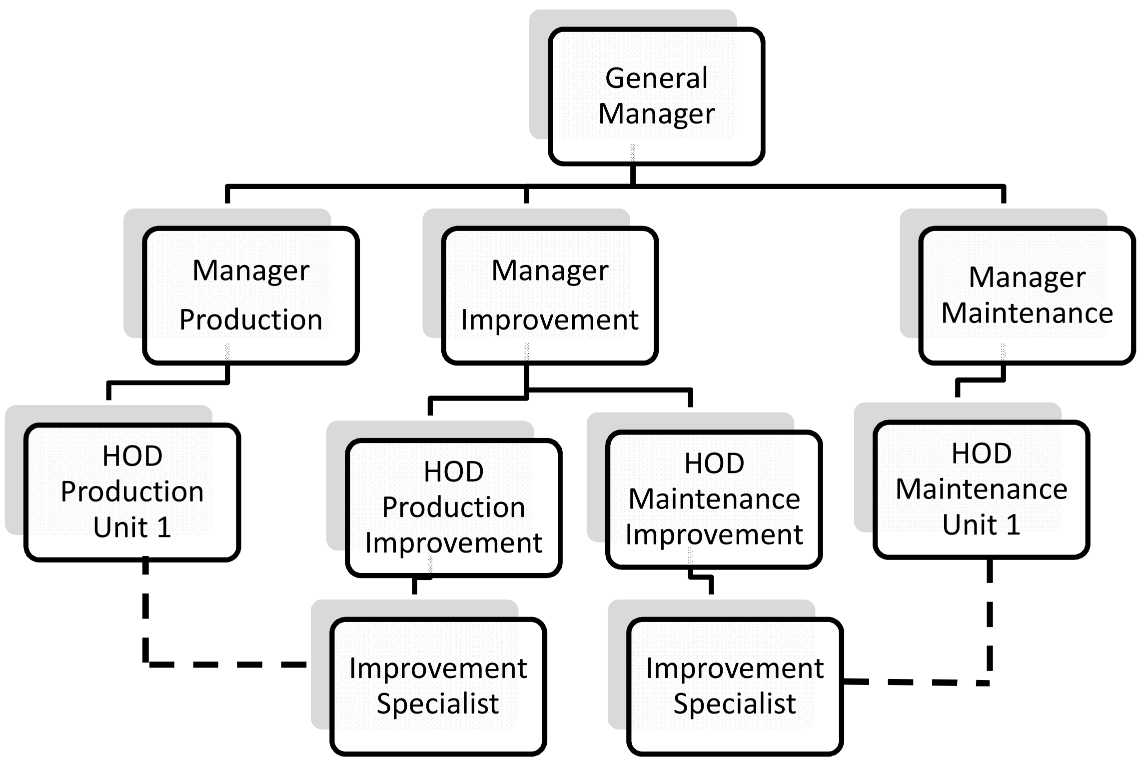


Figure 48 – Proposed structure for a MBP integrating an improvement department

Systems and processes need to be aligned to ease the CI initiative. This includes simple systems to identify, measure and track specific process variables and/or financial data. Added to this, processes need to be optimised for easy information capturing. Simplicity is the crux of this. It should not be a difficult task to obtain any information from the system, and processes should be measured without hindrance. The CI Programme will fail if the Improvement or Operational Team find it impossible to collect information from complicated systems.

Once the vision, structure, processes and systems are in place, one should identify the KVD's that would provide highest value to the organisation. In support of this, the necessary KPI's need to be developed, that will be used to measure effectiveness of the programme, the team and the individuals. KPI's represent a set of measures focusing on those aspects of organisational performance that is most critical for the current and future success of the organisation (Parmenter 2007:1). With this in mind, KPI's should be developed in such a way that any deviation from the standard should be acted on immediately. It should be meaningful and well defined. KPI's that are designed to track performance against CI, should be applicable to every employee in the business.

The strategy of the organisation will feed into the CI model and provide the cornerstone for decision making of all levels of the organisation. However, it plays a much more vital role. Bateman (2005) found that CI programmes are very often not sustainable. In research conducted on the automotive industry, it is suggested that three elements are necessary to promote sustainability of CI initiatives. These are as follows:

- The need to follow the PDCA loop in closing out actions
- The need for an enabling process to allow CI to take place
- A supportive management infrastructure

Bateman (2005) also concludes that infrastructural support is required by means of a dedicated CI team/individual, as well as strategic direction. The proposed strategic intent includes all of these elements, and should provide for solid direction of the improvement effort.

7.1.2 Defining Continuous Improvement Elements – Phase 2

An MBP can be defined as a system with various processes interacting with one another. From the survey results, five elements surfaced as being important in an MBP. These are as follows:

- Improvement in the Process
- Improvement in the Quality
- Improvement in the Efficiency
- Reduction in Cost
- Reduction in Waste

There is clear intention to improve the Process, but Quality, Efficiency, Cost and Waste are all related to the effectiveness of the process. In any MBP the structure is dominated by two main factions – The Production Department and the Maintenance Department.

The production function in a MBP is made up of three distinct work cycles. This is shown in Figure 49.

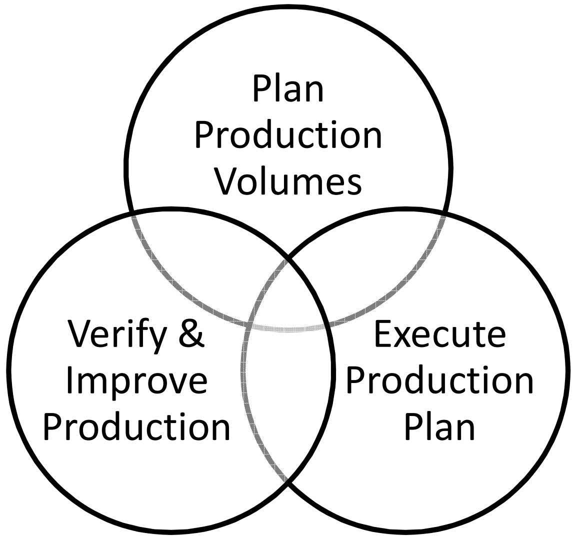


Figure 49 – Production work cycles in an MBP

Production volumes are planned according to the budget. These include various efficiencies related to usage of ore, water, electricity, chemicals, reductants etc. The production plan also dictate the waste production from such a facility and may include, but is not limited to, slag volumes, fines generation, sludge formation etc. All products produced are subjected to a quality specification, which may include, but is not limited to chemical analysis, size analysis etc. Any deviation from the plan will lead to lower income and/or higher costs, and hence affect the bottom line.

Figure 50 shows the work cycles for a typical maintenance team on a MBP.

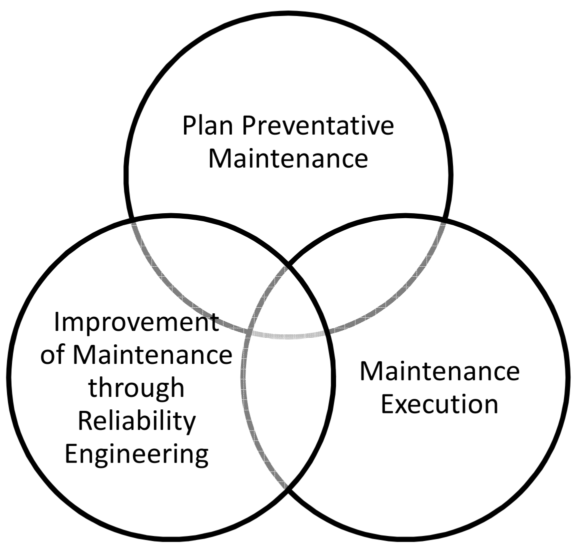


Figure 50 – Maintenance work cycles in an MBP

If a preventative maintenance strategy is followed, planning and scheduling of all maintenance activities take place. This is followed by maintenance execution of the plan. Any equipment or methodology improvement, in order to enhance availability or utilisation, is controlled through a third work cycle known as Reliability Engineering.

To remain competitive in this environment, a MBP should always be at the bottom of the cost curve (Figure 51).

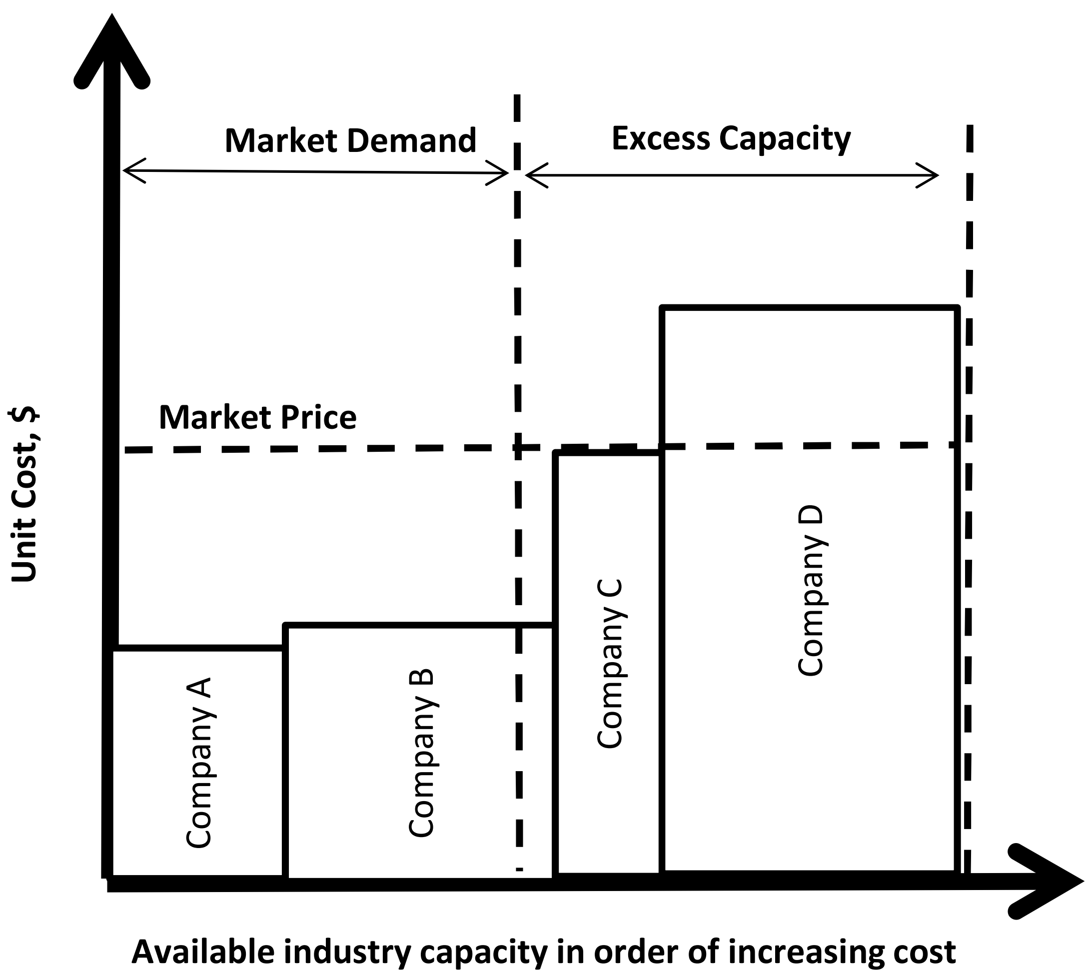


Figure 51 – A generic cost curve (McKinsey, 2009 - adopted)

Since the market price is determined by the demand of the product, it is more important than ever to ensure that costs are as low as possible. This is very true for MBP's, especially during recession times, where only the lowest cost producer will be able to sustainably exist.

Referring to Figure 49 and 50, it can be seen that even though planning of production and maintenance could be world class, execution can only be improved upon if a third dedicated work cycle is adhered to.

Both Process Improvement and Reliability Engineering fit into the category of CI. The aim of both these work cycles is to improve processes within the system.

An improvement in the process will naturally lead to:

- Improved quality (Q)
- Higher efficiency (E)
- Lower costs (C)
- Less waste (W)

It can therefore be said that Process Improvement is the primary aim of CI, with this being achieved by focussing on improvement of quality and efficiency, and reduction in costs and waste. Figure 52 shows the relationship described above.

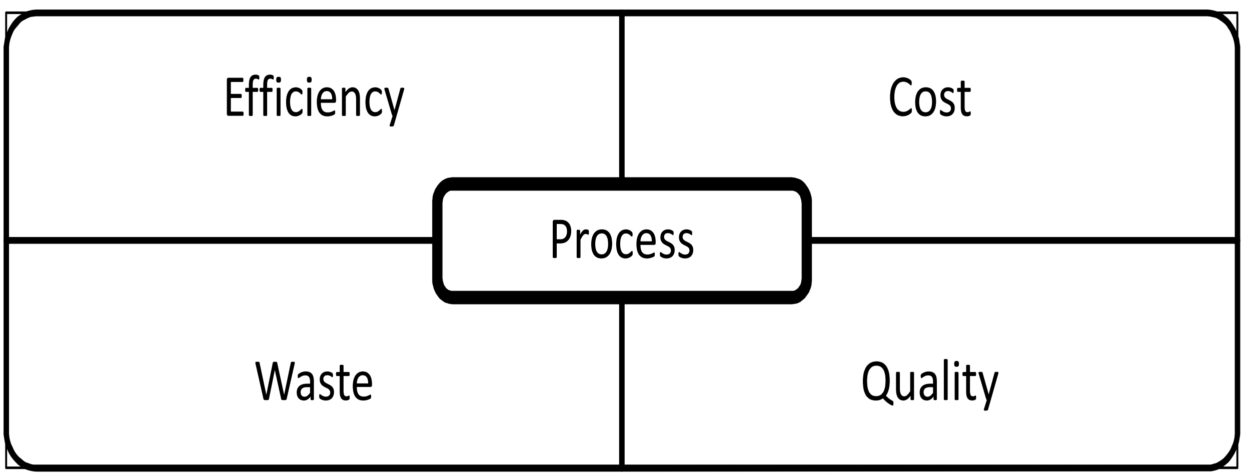


Figure 52 – Elements of the Process that will lead to general improvement if optimised

KPI's set up during Phase 1 should be focused on the four elements (QECW) that would deliver maximum value in process improvement. All systems and processes should be aligned to develop and embed knowledge and understanding of the fundamentals that affect QECW of the process.

One might argue the need for a SHE element that contributes to the process and system as a whole. This is a very important constituent of doing business in the mining and minerals processing business, and should therefore already be included in the strategy and vision of the organisation. Since SHE does not have a primary influence on the processes involved in a MBP, for this study, it is not included. It must be noted though that the same principles can be applied on improvement of any SHE process, and hence the necessity of this model to be applied to all functions within an MBP.

7.1.3 Implementing the Continuous Improvement Cycle – Phase 3

The objective of this study is to determine whether a continuous improvement model could be developed that comprises some of the more important elements of the established CI theories in practice today. It is also an objective to develop the model in such a way that it can be easily introduced into an MBP.

Figure 53 shows theproposed CI model for a MBP, which henceforth will be referred to as the Hexagonal Improvement Model (HIM). HIM is an amalgamation of the established theories into one model which can be successfully applied to a MBP.

HIM consists of six critical steps to ensure CI is achieved on an MBP. Each step is underpinned by a sequential governing process that should be used in executing that step. This is shown in Figure 54. This three step governing process assists in structuring ideas and thoughts around the process being addressed in that specific step.

The three step governing process is summarised as follows:

- Plan (P)
  Plan the work required in this step. Note any changes made to the plan, and plan subsequent changes if necessary.

- Focus (F)
  Constantly focus on the plan made. Ensure that the objectives are clear and that retrospection is done regularly to assess adherence to the plan.

- Deliver (D)
  Deliver on the objectives set in out in the plan. Analyse shortcomings, and repeat if necessary.

These three steps are an adaptation from the classical PDCA cycle, but can be effectively utilised to ensure focus on the objectives and successful completion of the specific step in the HIM.

A specific toolkit that is recommended for each step will also be discussed. These tools can be used by the CI Practitioner, not only to successfully execute the specific step, but also prepare for the next step.

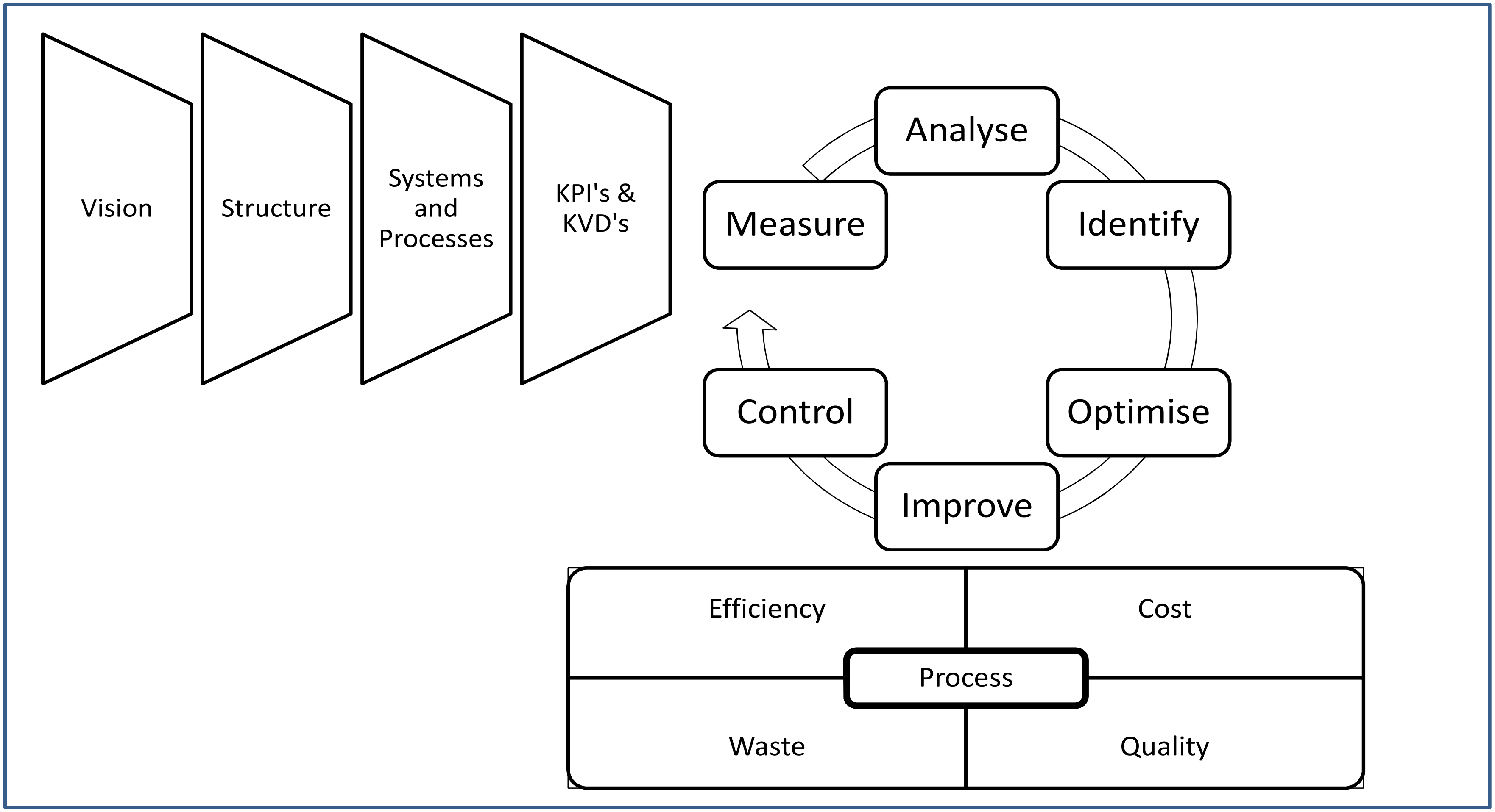


Figure 53 – The Hexagonal Improvement Model proposed for an MBP. The six step CI cycle is shown, built on the base of the four critical parameters of an MBP success. The strategic intent is feeding the CI cycle

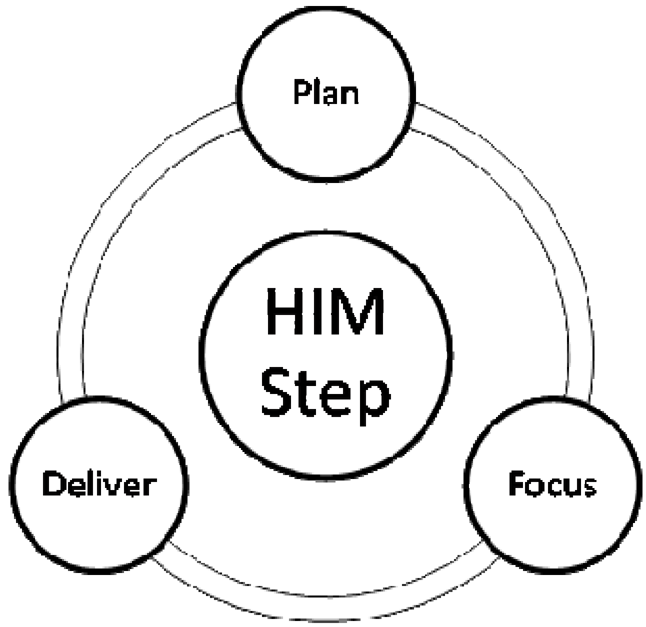


Figure 54 – The three step governing process that supports each of the six steps in the HIM.

7.1.4 Step 1 – Measure

In the classical SS methodology, one would follow 5 steps to achieve continuous improvement. The first step is *Define*. In this step one would define a project that would be in line with the organisation's objectives (Shankar, 2009; McCarthy *et al,* 2005; Britz, 2009). Typically if the objective is to improve quality of products, one would define a project that would aim at improving quality. If one follows this approach, one might focus all attention on a part of a MBP that does not affect QECW. Improvement of QECW would ultimately improve the process and system within a MBP. It is thus easy to misalign effort, time and capital on a part of the process which is not necessarily going to improve the specified KPI's. It very often happens that managers spend time on improving a specific problematic area in the process, which will not necessarily add to the improvement of the system as a whole.

It is therefore proposed in this model that the first step in the journey to continuous improvement should be *Measure*. Frequently it is not easy to identify where exactly in the process one might have a problem of inefficiency.

During the first step, one would measure a specific process and its variables. One is guided by the strategic input which includes specific KPI's that align with the organisational goals and objectives.

Data collection should take place in the measurement phase, and it is important for the improvement specialist to quantify the data set. Often data may be difficult to obtain. In a case like this, it is imperative to consider the original design intent. This data can be compared to current state, and as such one may be able to determine a short fall. In most cases one would be able to draw a baseline of current performance from historical data or trends. This in combination with a detailed process map should deliver adequate information to understand the problem. According to Hunt (1996), process mapping is an excellent management tool used by teams to better understand the current processes and to eliminate or simplify those processes needing change.

Once the process and its associated steps have been mapped, one can measure specific input and output, and do a comparison with the original design specifications. Measurement will also be limited to variables in the process. There is no use in measuring those elements in a system that remains constant. This is where process mapping will play a critical role. The process map will reveal all necessary variables in the process.

The purpose of measuring is to obtain, organise and represent data. This data will be a yardstick of current performance, but will also serve as a baseline to compare any improvement against. It is vital that a proper definition is given of which variables in the system will be measured. Added to that, the validity of data has to be audited, to ensure accuracy, as any invalid data could lead to distracted focus.

Figure 55 shows Step 1 with some of the suggested tools to be utilised

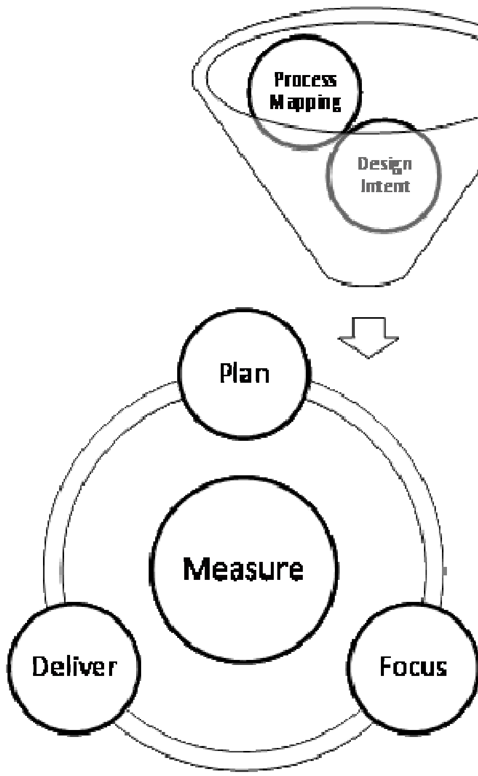


Figure 55 – The Measurement step in HIM detailing potential tools to be utilised

Once the data collection has been done, and validity of the data is assured, one can move to the next step in the model.

7.1.5 Step 2 – Analyse

The next step in the CI model is to *analyse* the data from the measurement step. The analysis step is also a remnant of the SS model. In the analysis phase of the DMAIC cycle of SS, the improvement team utilises statistics, and other graphical representations to develop a problem statement. This step is key to any SS project's success, and is a critical tool in any CI process. This is due to the unambiguous nature of valid data – it will clearly indicate where improvement is required within the process. It is for this reason that it is included in this model. On any MBP, there are multiple variables that have an effect on the process. There are also some interacting processes, and consequently some variables may interact as well. If one is faced with a large data set with a complex process map, it may be necessary to focus on specific details within the process map. The analysis phase is used for this purpose.

By utilising various statistical and other tools, the improvement specialist will not only be able to determine what effect each variable has on its own, but also what the effect of the variables as a group have on the process. Only then can one move onto the next step of the model.

The tools required for analysis are copious. Some of these tools are shown in Table 6. These tools, as well as numerous other tools could be used to identify specific elements in the process where variables are unstable or out of control.

Table 6 – Some tools that could be utilised in the Analysis Step of the CI model

Statistical and Technological tools used for Analysis	
Scatter Diagrams	**Regression Analysis**
Histograms	**Analysis of Variance**
Pareto Charts	**Fishbone Diagrams**
Failure Mode Analysis	**Affinity Diagrams**
Check Sheets	**Statistical Process Control**

Step two in the HIM is shown in Figure 56, with the associated toolkit.

7.1.6 Step 3 – Identify

Once the analysis is done, one can now *identify* which of the variables will have the biggest impact on improving the process. Up to this point in the model, no improvement has been achieved. One has only measured and analysed data. The identification of a problematic area is the first step in improvement. It is therefore very important to have an element of governance from this point forward. The improvement specialist will be responsible to draft a proper problem definition based on the data analysis. This problem statement will have to be aligned with the strategic intent of the organisation. It would also be valuable to determine to what extent the identified problem is affecting QECW of the process. After the initial problem statement has been drafted, one would have to scope the problem.

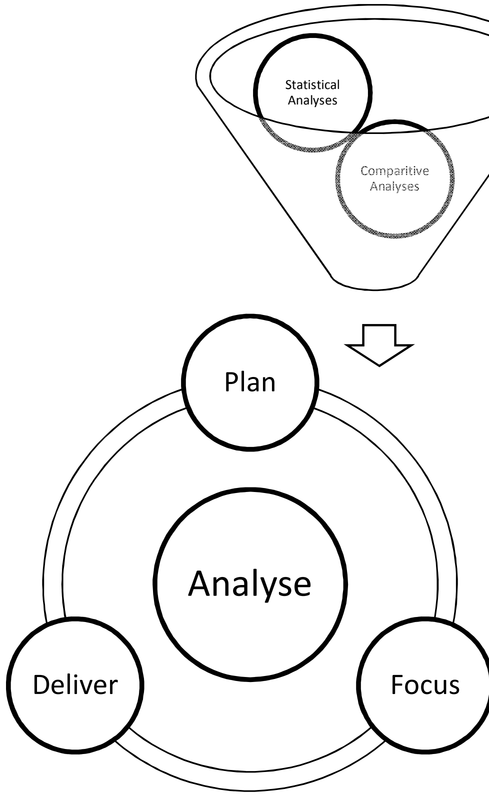


Figure 56 – The Analysis step in HIM detailing potential tools to be utilised

In TOC, the first of the five focussing steps is *Identify*. This step focuses on identification of the current constraint in the process - that is the single part of the process that would limit the rate of production. The TOC approach clearly intends to improve throughput, which may not necessarily be the strategic intent of the MBP operation. The principle of *Identification* remains valid. Optimisation of QECW will lead to process improvement, and therefore in the *Identification* step of this model, one would identify which variable has the biggest effect on those four elements.

The deliverable in this step is the identification of a variable or variables that has a significant effect on the QECW. Once agreement on this has been reached, one would move to the next step in the model. It must be noted though, that the KPI's and KVD's have to be kept in mind. The variable selected in this step cannot be something out of the control of the operational team.

In Figure 57, the Identification step is shown with associated tools used to assist in governance.

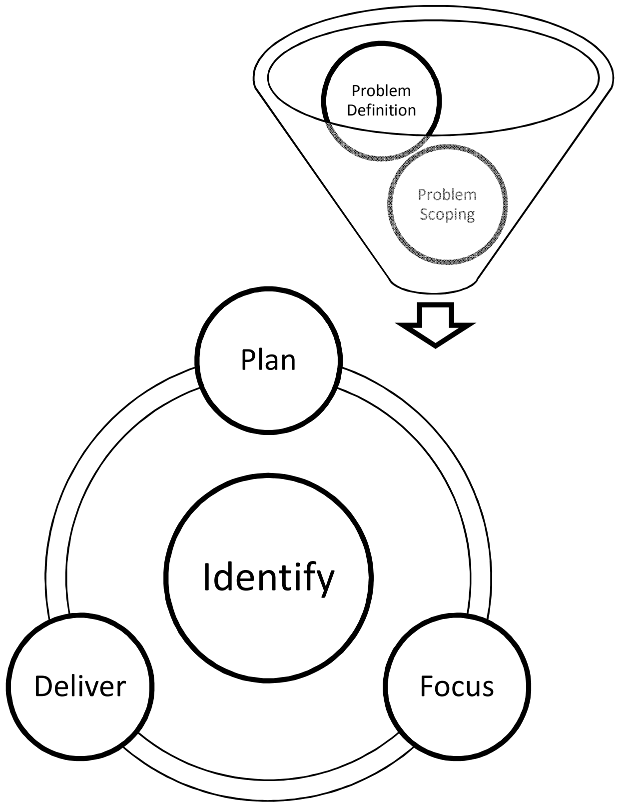


Figure 57 – The Identification step in HIM detailing potential tools to be utilised

7.1.7 Step 4 – Optimise

This step is the first improvement step. The aim in this step is to optimise the variable identified in step 3. In SS, this step is known as *Improve* and in TOC this step is known as *Exploit*.In SS, the *Improve* step is utilised by the Improvement Specialist to identify, design and implement the most cost effective solution to a specific problem. It usually then goes into a project phase. In TOC, the constraint is exploited, meaning that the utilisation of the constraint is improved, which should lead to higher throughput for the system as a whole.

In this model, the Optimisation step will be used to optimise the variable in its current state. No complex change to the variable should be considered during this step. The idea is to have quick measurable improvement without initialising innovation or capitals spend. In a MBP this may mean a change in setpoint for the process.

The high variability of raw materials very often requires small changes to parameter set points to achieve desired results. Typical examples would be a change in reductant mix on smelters or a change in open side setting for an ore crusher. The operational team will play an integral role in these decisions.

The process of *Optimisation* is a LM approach. The improvement specialist will again play an integral role in assisting the operational team in governance of the *optimisation* step of the CI model. Throughout the *Optimisation* step the focus should always be the promotion of a lean system, i.e. optimising the processes in such a way that it promotes simplicity of the system. It is very important not to add any complexity through optimisation. The aim is to simplistically and systematically optimise a variable through quick measurable improvements.

The Improvement Specialist has a specific role to play in *Optimisation*. It is imperative that prioritisation of *Optimisation* opportunities is done. Again, this can be through Decision Matrices or any other decision making tool. Once prioritisation is complete, execution of the optimisation project should follow.

The execution itself should be carried out by the operation team, with tracking and monitoring being done by the improvement team. For governance purposes it is very important to keep proper records of all changes, and note all resulting consequences of the change, specifically the effect on QECW. A good tool to utilise in this case would be the stage gate tracking tool for Project Management

Subordination has its origins in TOC. In TOC, subordination is used to review all other activities in the process to ensure that it is aligned with and support the constraint. In the *Optimisation* step, subordination will be used in a similar manner. It is important to verify whether any other variable or activity would influence the variable or activity chosen for optimisation. The effect of all other variables and activities should also be noted. Change to these variables or activities must remain minimal, but preferably the only change should be on optimising the chosen variable or activity. As with TOC, the primary objective in this step is to support the inefficient variable or activity, but not to the detriment of the entire system.

Figure 58 shows the Optimisation step and associated tools to be used.

7.1.8 Step 5 – Improve

Step 6 is a remnant of Six Sigma. The purpose of this step is to *improve* the identified variable. In the previous step, the purpose was to obtain stability on the variable. Once steady state is achieved, it is time to look at improvement of the variable. Shop floor involvement in this step will be very important, as idea generation for improvement is cardinal. The improvement specialists will facilitate this, typically through an idea generation session (IGS). Innovative ideas for improvement are the objective in these sessions.

It is of vital importance that an MBP develop a culture in which innovation is treasured and promoted. The result of an innovative culture is that new ideas are developed in a team where all suggestions are adjudicated in a constructive manner, and futile proposals are not penalised. (Anderson et al, 1992).

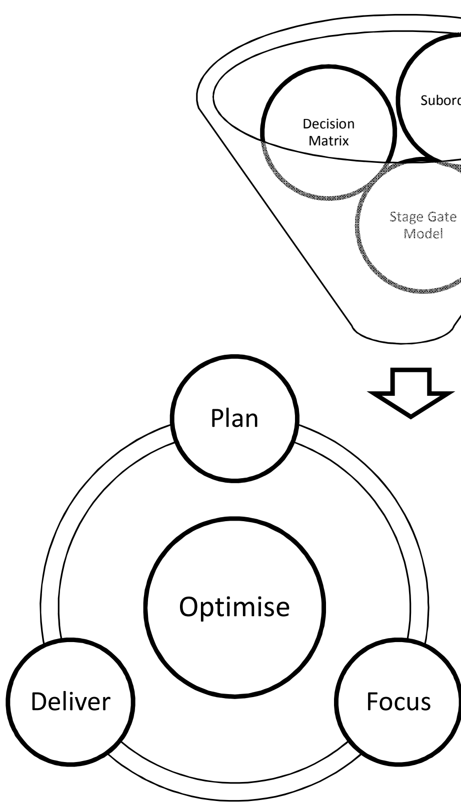


Figure 58 – The Optimisation step in HIM detailing potential tools to be utilised

The improvement specialist should focus on the variable in question, and should guide the team on the four sources of innovation from within the organisation, as identified by Drucker (2005):

- Unexpected - Unexpected success, failure or outside event
- Incongruity - Discrepancy between what ought to be and what is
- Process Need – A necessity to change
- Industry of market structure change – The needs of consumers change

Although not all ideas generated will have an innovative edge, it is important to always drive new ways of thinking. One can very easily fall back into old habits, and established ways of doing things. Unfortunately, in the ever changing, and fragile market MBP's operate in, only those who really embrace innovation will be able to withstand the wave of economic slumps.

Once idea generation and innovation activities have been concluded, the improvement specialist needs to prioritise these ideas. It is proposed that prioritisation is done by means of two steps. Firstly, all ideas should be plotted on a value-ease matrix (Figure 59). Priority should be given to high value, low ease projects. Once prioritisation has been done on the value ease matrix, the next step of prioritisation commences. It is recommended that a decision tree, combined with expected monetary values (EMV) be used. EMV is calculated by considering both probability of a certain outcome as well as monetary value (Clemen & Reilly 2001:115). A simple example of a decision tree incorporating probability, as well as monetary value is shown in Figure 60. From Figure 60 it can be seen that decision making is eased through this technique. In this example, the decision maker should not buy a lottery ticket.

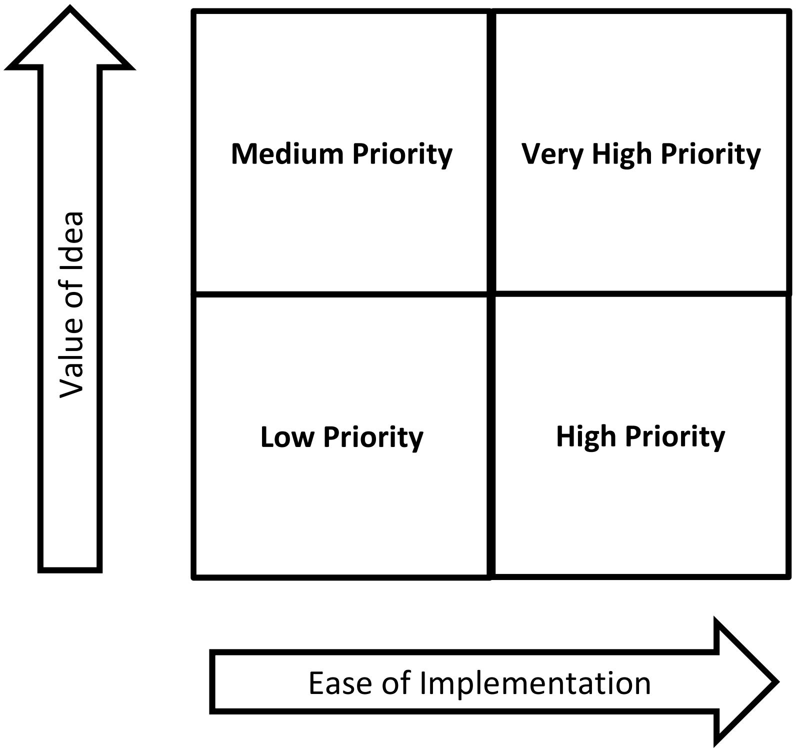


Figure 59 – A typical value ease matrix that could be used for prioritisation of innovative ideas.

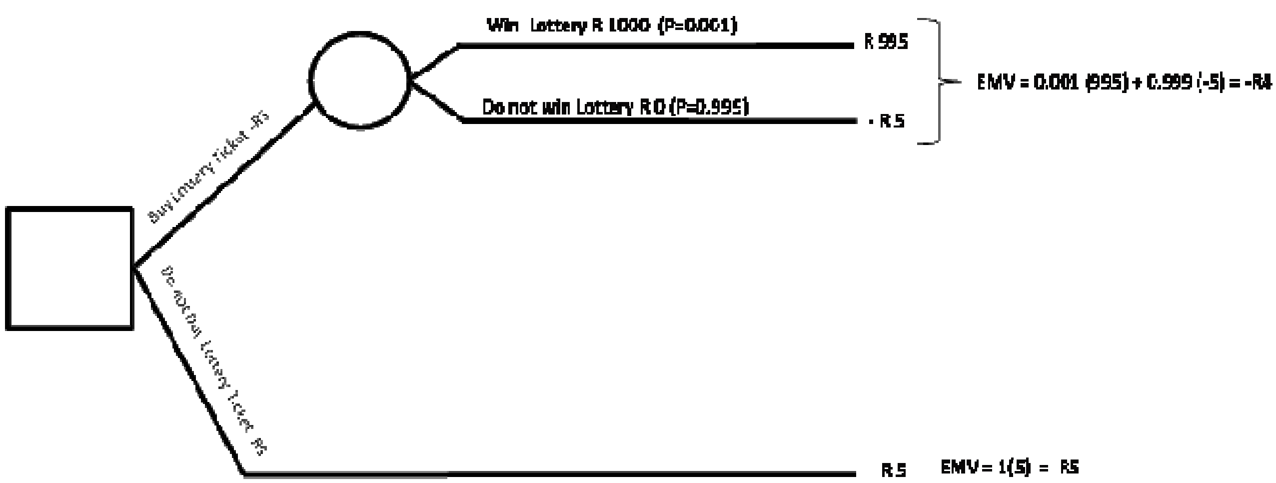


Figure 60 – A typical decision tree, detailing the EMV of a simple decision on whether to buy a lottery ticket.

Once prioritisation is complete, the concept of exemption can be introduced, i.e. involving the innovator in the development of the idea. This, of course, is subject to staff compliment, but should be encouraged as innovator participation will richly enhance the project and ultimately the improvement effort.

Idea Generation, Innovation and Prioritisation and Tracking of Projects are all tools in the process of improvement. This is shown in Figure 61. Once these activities have been concluded, an improvement project is launched. Again, the Improvement Specialist ensures that proper governance is adhered to.

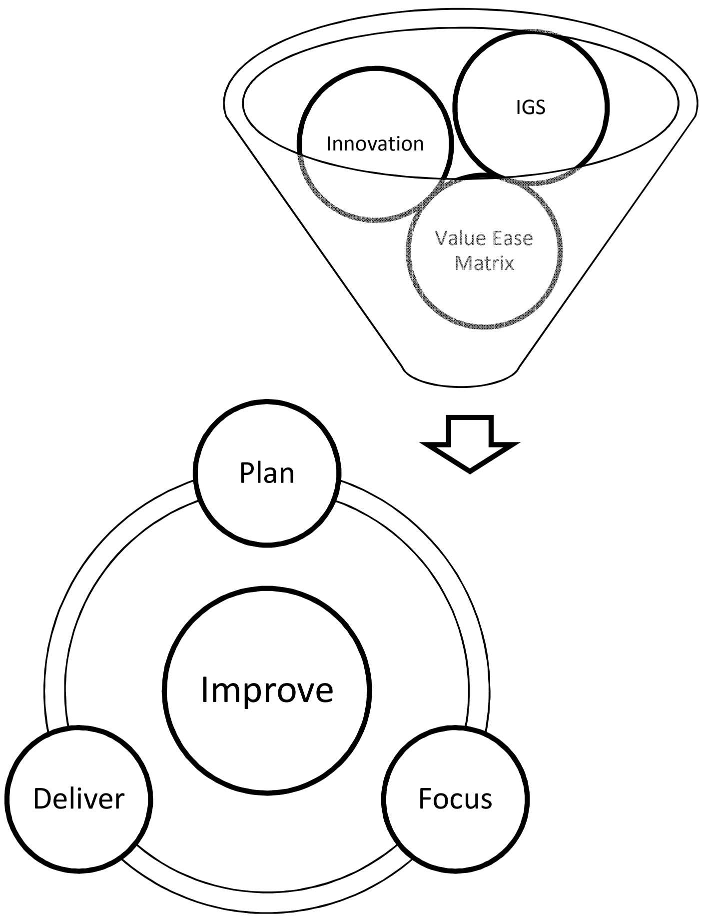


Figure 61 – The Improvement step in HIM detailing potential tools to be utilised

7.1.9 Step 6 - Control

The next step in the model proposes that the improvement now needs to be controlled. This starts with the execution of the project. Execution of the project is a systematic process, which consists of activities feeding into tasks.

Steyn (2002:3) defines a project as any planned, temporary endeavour undertaken to create a unique product, service or other complete and definitive outcome within a limited time scale and budget. Considering this definition, it can be seen that improvement initiatives should be considered as projects. It is recommended that a Critical Chain project approach should be followed. This TOC approach provides the organisation with the opportunity to properly schedule resources for the improvement project, with the added benefit of ensuring that the project has a well-defined buffer.

The Improvement Specialist has the responsibility to initiate and administer the project. This includes the following:

- Defining the scope
- Drawing up a responsibility matrix
- Drawing up the Gantt Chart
- Scheduling the resources

Tracking of activities, and consequently the tasks it feeds into, are vital. In the planning phase, milestones on the project had to be identified, and management thereof is key to project management success. The improvement specialist has to be insistent in ensuring that deadlines are met, and milestones achieved on time, and within budget. Regular tracking meetings are essential in ensuring that the project remains in control.Since improvement initiatives fall within the project domain, it is important to note that the project will end. The most important deliverables from the improvement initiative are systems and processes that are sustainable.

The aim of these systems and processes is to ensure that the improvement is sustained into the future. Tracking of the improvement initiatives extends further than the project itself. The improvement specialist needs to define when steady state will be reached on the project. Once steady state is achieved, the project needs to be audited to determine success or any shortcomings.

After the project close out, tracking will continue for another 6 months. Thereafter, the processes and systems that were put in place needs to ensure stability and sustainability of the improvement. It is important that the operational team need to keep the focus on this specific metric by measuring KPI's that will assure that it does not return to an unstable state. In Figure 62 Step 6 is detailed.

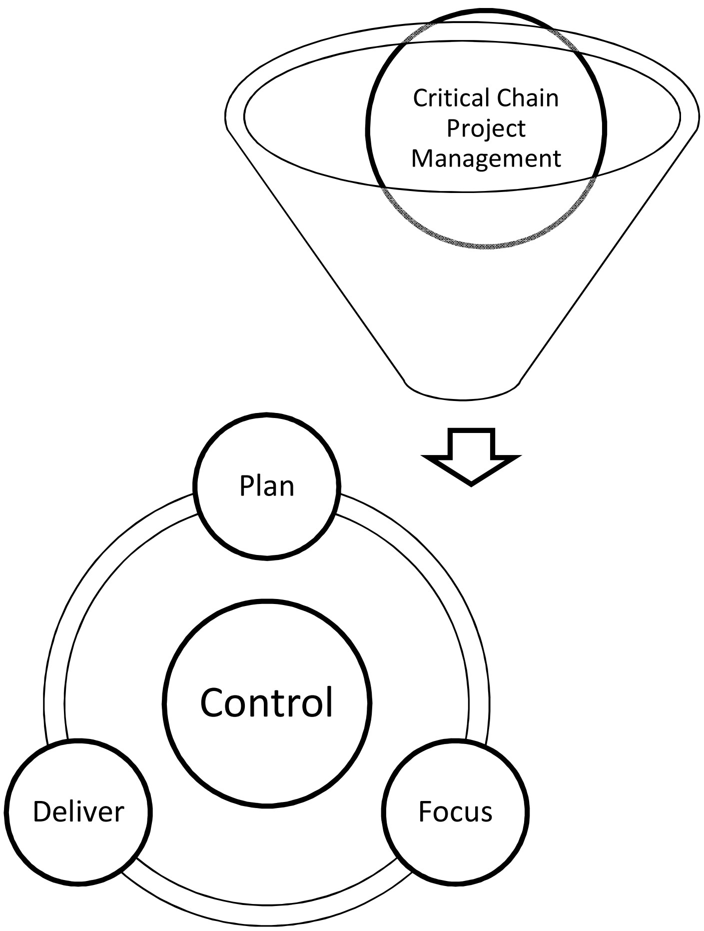


Figure 62 – The Control step in HIM detailing potential tools to be utilised

7.1.10 Continuous nature of model

In order to achieve CI, the model needs to be cyclical in nature. It is therefore important start with step 1 again after improvement has been sustained. One can obviously work on more than process and/or variable at a time, but it needs to mutually exclusive. By following the hexagonal model of improvement, continuity of improvement will achieved.

7.2 Comparison to Kumba Model

From literature, it was seen that De Jager et al (2003:321) developed a CI model for Kumba Resources (See Figure 17). It is important to understand the differences between the HI-model (Figure 53) and the Kumba Model.

The HIM is based on the core strategy of the business. It requires the correct structure, systems and processes to be in place. This is to ensure that CI is supported in a top-down approach. From the strategy, KVD's and KPI's are identified, which feeds the CI cycle. The Kumba Model requires a case for change. It is not defined on which the case for change will be based. Over and above this, it is difficult to build a case for change, if one has not measured the process. The HI-model first calls for measurement, before the case for change is presented.

Both the HI-model and the Kumba Model requires the use of KPI's,however the HI-model also requires the identification of KVD's, whereas the Kumba Model focusses on Key Performance Drivers (KPD's). The HI-model is more focus on total value added to the business.

The CI-loop for both models is focused on analysis, and identification. The difference in the HI-model is the focus on optimisation before improvement. The Kumba Model does not dictate optimisation of current processes before improvement thereof. This is a critical step in improvement, as no improvement will be achieved without stabilisation of the process.

The control of improvement by means of tracking and monitoring is emphasised in both models.

In contrast to the HI-model, the Kumba Model specifically focusses on the importance of communication, buy-in and visibility of the CI process. This is a very important element, which has to be considered in all initiatives rolled out to the shop floor. It is known that certain nuances exist in a South African context, and that diversity in the workforce need to be considered, however for this study, it is specifically excluded.

The HI-model is also focussed on Process Improvement, hence the CI cycle is built on the QECW principle. The Kumba Model was designed with the whole organisation in mind, not necessarily the Process Departments. Again, the principles in the HI-model could easily be applied to all supporting functions within the organisation, however for this specific study, it is excluded.

Chapter 8

"Realists do not fear the results of their study."
Fyodor Dostoyevsky

8.1 Case Study – South African Ferro Alloy Smelter

8.1.1 Background

The model proposed in this report was utilised in a case study at a South African ferro alloy smelter. The plant rarely achieved its production targets, and hence it was proposed to utilise the six step model described in this report to identify and improve some process variables that would ultimately lead to an improved process.

8.1.2 The Improvement Process

Strategy

A rigorous process was followed to identify KVD's. This was done utilising a financial model to determine which process variables are key drivers of performance. From this it was seen that an improvement inyield is a KVD that could potentially add significant value to the business. In order to improve this, a universal KPI had to be identified. This KPI had to be a measurement that could universally be applied in determining yield status. Adherence to Tapping Cycle was used as KPI to track and monitor success of the improvement project. This KPI is a universal measure that, if adhered to, would result in improved yield, and consequently improved efficiency. The plant was aligned with regards to corporate strategy and structure, in order to achieve CI. The systems and processes that had already been entrenched were suitable to support and encourage CI.

Measure

This specific plant had been struggling to control and manage tapping cycles of the submerged arc furnaces (SAF's).

The hypothesis is that adherence to tapping cycles would result in yield improvement. An improvement project was launched on one of the smelter's furnaces.

The adherence to tapping schedule was *measured* to determine the baseline of the furnace. A process map, detailing all steps in the tapping process was drawn up. Each step was individually mapped, and measured. Measurement was done on a 24 hour basis over a 2 week period. In total, 56 shifts were measured to determine current performance.

Analysis

The measured values were analysed and compared to historical performance It was also benchmarked against typical plants and processes. A pareto analysis was done compared against best performance. During *analysis* of the measured values, it was found that indeed adherence to tapping schedules were extremely poor. Slag and metal analyses, which are indications of yield, showed variable results.

Identification

It was *identified* that the tapping process was not in control. Large variances were observed between taps, as well as the amount of metal and slag tapped. A lot of time was wasted in preparation of tapping, and no real system existed to guide tapping crews on what is expected of them. From this a Problem Statement was defined. The problem was scoped, and all inclusions and exclusions were identified.

Optimisation

In order to *optimise* the way metal and slag are tapped, more emphasis was placed on tapping cycles, and time was spent on the shop floor to ensure adherence. All other variables were subordinated to this change. The primary goal was to achieve steady MWh/t between taps, which would ultimately lead to a more continuous tapping cycle.

It was seen that the power input between taps steadily stabilised. The rhythm and routine that was created by introducing this KPI resulted in a more stable and controlled tapping of the furnace. Slowly it was observed that yield had improved, however the KPI was still not within control band limits.

Improvement

At this point in the process, an IGS was conducted. The purpose of the IGS was to generate innovative ideas that could be used to improve the tapping cycles, and consequently the yield of the furnaces. In order to *improve* the process, it was decided to tap the furnace at fixed time intervals, instead of power input. This was a radical and innovative change to the way things have been done previously. A lot of time and effort was put into ensuring the shop floor buys into the concept of tapping at fixed time intervals.

Control

By utilising Critical Chain Project Scheduling, the project was managed. In a matter of weeks, the tapping cycles were in complete control, and as a consequence, the power input between taps also got into control. The yield improved significantly, resulting in higher throughput of metal. In order to *control* the new improvement, new systems were put in place. These included an escalation protocol and automated tapping indicators. After these control measures were put in place, the improvement project was handed over to the Production Execution team, with the Improvement Team monitoring improvement for a period of six months after project completion, and since then all parameters have been in control.

Outcome

The improvement has been significant, but more importantly for this study, it showed the model to be applicable and successful in an MBP environment. The buy-in at more senior levels was instantaneous, and all process and improvement practitioners found the structure ofthe model easy to follow.

The utilisation of the improvement tools was found to be more challenging, as coaching and training were needed to perfect the techniques.

A paradigm shift was also required to move from an operational mind set, to an improvement mind set. This also proofed to be a challenge, as the culture on the shop floor were hesitant to trying new things. This was overcome by an encompassing and thorough communication strategy aimed at buy in from the shop floor. Within one month, all shifts embraced the tap-on-time principle, and as such the new improvement was found to be sustainable.

Chapter 9

"To improve is to change; to be perfect is to change often."

Winston Churchill

9.1 Conclusions and Recommendations

Current CI Tools

A literature review shows that current CI models have not been developed specifically for MBP's. The models in existence today, have been specifically developed for assembly type plants, and do not directly apply to continuous operations, such as MBP's.

The survey conducted, confirmed the fact that practitioners working in MBP's agree that not any one model will specifically address the issues experienced by MBP's. The majority of respondents agree that a combination of current techniques could be successfully applied to MBP's.

There are many aspects of current models that have applicability to MBP's; however each model was designed with a specific objective in mind. SS was developed to ensure quality standards are met, whilst LM are used to ensure that all waste is eliminated from a system. TOC focuses on throughput increase, by elimination of any bottleneck within the system.

To improve processes within an MBP one requires a more rigid and thorough approach, that would address multiple factors, and hence a consolidation of models are preferred.

A specifically designed CI Model

The survey conducted showed that the majority of respondents feel that MBP's could benefit from a CI programme, and that it could be successfully implemented if specifically designed with the CI aspects of an MBP in mind.

Respondents reacted positively to all individual models; however the majority of respondents felt a combined model will proof successful at an MBP.

It was found that no CI model would be successful if it is not underwritten by the strategy of the organisation. It is also important that the right structure and performance measures are in place. This will ensure that employees only focus on the drivers that add value to the organisation.

The new model that is proposed incorporates elements from SS, TOC and LM. It is built on the four most important aspects to process improvement. These are as follows:

- Improved quality (Q)
- Higher efficiency (E)
- Lower costs (C)
- Less waste (W)

The model is made up of six steps to improvement, with the order of the CI cycle suitable to an MBP. The toolkit suggested for the model, is easy to use and applicable to all steps in the CI cycle.

A case study was conducted on the improvement of yield in a Ferro Alloy smelter. The model and the MBP environment is a very good fit, as the improvement initiative in the case study returned positive results.

It is concluded that indeed this model can be successfully applied to an MBP. It is recommended that future studies should consider implementation of this model into different mineral industries and MBP's. Future studies around the inclusion of HSEC principles would be valuable for MBP operations. It is also recommended that the cultural impact of implementation of the model should be studied.

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Appendix

Survey

Section A – Personal Details

Section A	Background Information	
Respondent Industry	*(Select the most appropriate answer)*	*Mark Here*
	Pyro Metallurgy	☐
	Hydro Metallurgy	☐
	Minerals Processing	☐
	Physical Metallurgy	☐
	Resources (incl Mining)	☐
	Other	☐
Respondent Experience	*(Select the most appropriate answer)*	*Mark Here*
	< 5 years	☐
	5 - 10 years	☐
	10 - 15 years	☐
	15 - 20 years	☐
	> 20 years	☐
Management Level of Respondent	*(Select the most appropriate answer)*	*Mark Here*
	Patterson C - Level	☐
	Middle Management	☐
	Senior Management	☐
	General Management	☐
	Executive Level	☐
	Other	☐
Respondent Current Role Discipline	*(Select the most appropriate answer)*	*Mark Here*
	Metallurgy (Production)	☐
	Metallurgy (Technical)	☐
	Metallurgy (Design & Development)	☐
	Maintenance	☐
	Project Management	☐
	Operations Management	☐
	Strategy Development	☐
	Other (Please Specify)	☐
Respondent Business Size	*(Select the most appropriate answer)*	*Mark Here*
	Multinational Corporate	☐
	National Corporate	☐
	SMME	☐
	Parastatal	☐

Section B - Exposure to CI Models

Section B	Defining Continuous Improvement	
	Which one of the following definitions best describes your understanding of Continuous Improvement	*Mark Here*
1	Sustained Improvement targeting the elimination of waste in all systems and processes of an organisation	☐
2	A gradual change of ongoing improvements which aggregate over a period of time to provide visible proof that things are	☐
3	An organisation-wide process of focused and sustained incremental innovation	☐
4	A statistical approach of idenitifying bottlenecks in the organisation, which is then managed and improved through a projects approach	☐
5	Other (Please Comment Below)	☐
Comment:		

	By using the opposite scale, please rate to what extent the following elements are of importance in continuous improvement in your organisation	*Mark Here*
1	Quality of production	
2	Throughput of production	
3	Process Improvement	
4	New Technology Development	
5	Costs	
6	Efficiency Improvement	
7	Competitiveness	

SCALE	TERM USED
5	Decidedly Important
4	Very Important
3	Important
2	Somewhat Important
1	Unimportant

	Which of the following CI strategies are you familiar with?	*Mark Here*
1	Six Sigma	☐
2	Lean Manufacturing	☐
3	Theory of Constraints	☐
4	TQM	☐
5	Other (Please Specify)	☐
Comment:		

	By using the opposite scale, please rate the importance of the following CI strategies to your specific industry.	*Mark Here*
1	Six Sigma	
2	Lean Manufacturing	
3	Theory of Constraints	
4	TQM	
5	A combination of the above	

SCALE	TERM USED
5	Decidedly Important
4	Very Important
3	Important
2	Somewhat Important
1	Unimportant

Section C - Knowledge of TOC

Section C	Theory of Constraints	
	Which of the following definitions best describe The Theory of Constraints according to your understanding	*Mark Here*
1	A management approach which focuses on improving bottleneck processes, to continuously improve the performance of manufacturing operations	☐
2	A body of knowledge about systems and the interaction of their component parts which rely on five focussing steps (Identify, Exploit, Subordinate, Elevate, Repeat & Prevent Inertia) to guide the system improvement efforts.	☐
3	A method to pin point underperforming areas in the manufacturing process, and improving it	☐
4	A structured method to identify the weakest link in the production chain, followed by the maximum utilisation of the bottleneck asset	☐
	Which, according to your knowledge, is the main driver of TOC?	*Mark Here*
1	Quality of production	☐
2	Throughput of production	☐
3	Process Improvement	☐
4	New Technology Development	☐
5	Costs	☐
6	Efficiency Improvement	☐
7	Competitiveness	☐
8	Other (Please specify below)	☐
Comment:		
	Have you ever been involved in an improvement initiative utilising TOC as strategy?	*Mark Here*
1	Yes	☐
2	No	☐
	If you answered yes, which of the following was the main driver of the improvement initiative?	*Mark Here*
1	Quality of production	☐
2	Throughput of production	☐
3	Process Improvement	☐
4	New Technology Development	☐
5	Costs	☐
6	Efficiency Improvement	☐
7	Competitiveness	☐
	Was TOC successful in addressing the challenges in the improvement initiatives	
1	Yes	☐
2	No	☐

Section D – Six Sigma

Section D	Six Sigma	
	Which of the following definitions best describe six sigma according to your understanding	*Mark Here*
1	An organised and systematic method for strategic process improvement and new product and service development, that relies on statistical methods and the scientific method to make dramatic reductions in customer defined defect rates	☐
2	Management approach which is project-driven, to improve the organisation's products, services, and process by continually reducing defects in the organisation	☐
3	Business process that allows companies to drastically improve their bottom line by designing and monitoring everyday business activities in ways that minimise waste and resources while increasing customer satisfaction by some of its proponents	☐
4	An organised, parallel-meso structure to reduce variation in organisational processes by using improvement specialists, a structured method, and performance metrics with the aim of achieving strategic objectives.	☐
	Which, according to your knowledge, is the main driver of Six Sigma?	*Mark Here*
1	Quality of production	☐
2	Throughput of production	☐
3	Process Improvement	☐
4	New Technology Development	☐
5	Costs	☐
6	Efficiency Improvement	☐
7	Competitiveness	☐
8	Other (Please specify below)	☐
Comment:		
	Have you ever been involved in an improvement initiative utilising Six Sigma as strategy?	*Mark Here*
1	Yes	☐
2	No	☐
	If you answered yes, which of the following was the main driver of the improvement initiative?	*Mark Here*
1	Quality of production	☐
2	Throughput of production	☐
3	Process Improvement	☐
4	New Technology Development	☐
5	Costs	☐
6	Efficiency Improvement	☐
7	Competitiveness	☐
	Was Six Sigma successful in addressing the challenges in the improvement initiatives	
1	Yes	☐
2	No	☐

Section E – Lean Manufacturing

Section E	Lean Manufacturing	
	Which of the following definitions best describe Lean Manufacturing according to your understanding	*Mark Here*
1	A strategy aiming for the ceaseless elimination of waste	☐
2	A philosophy of achieving improvements in the most economical ways with special focus on reducing waste	☐
3	A pull model (customer needs) that focuses an a reduction of over production	☐
4	A structured approach with various techniques focussing on the imporvement of the 4 M's - Man, Machine, Method and Materials.	☐
	Which, according to your knowledge, is the main driver of Lean Manufacturing?	*Mark Here*
1	Quality of production	☐
2	Throughput of production	☐
3	Process Improvement	☐
4	New Technology Development	☐
5	Costs	☐
6	Efficiency Improvement	☐
7	Competitiveness	☐
8	Other (Please specify below)	☐
Comment:		
	Have you ever been involved in an improvement initiative utilising Lean Manufacturing as strategy?	*Mark Here*
1	Yes	☐
2	No	☐
	If you answered yes, which of the following was the main driver of the improvement initiative?	*Mark Here*
1	Quality of production	☐
2	Throughput of production	☐
3	Process Improvement	☐
4	New Technology Development	☐
5	Costs	☐
6	Efficiency Improvement	☐
7	Competitiveness	☐
	Was Lean Manufacturing successful in addressing the challenges in the improvement initiatives?	
1	Yes	☐
2	No	☐

Section F – New Model

Section F	Development of a New Model	
	In your opinion, what are the five most important elements that should be present in the ideal CI strategy for a Metallurgical Process Plant (Please list a maximum of 5 elements)?	*Mark Here*
1	Project Management	☐
2	Quality Management	☐
3	Process Improvement	☐
4	Competitiveness	☐
5	Throughput	☐
6	New Technology Development	☐
7	Efficiency Improvement	☐
8	Cost Reduction	☐
9	Market Share Improvement	☐
10	Value Increase	☐
11	Waste Reduction	☐
12	Constraint Elimination	☐
13	Asset Optimisation	☐
14	Maintenance Management	☐
15	Other (Please Specify)	☐
	Do you believe that a process plant benefits from having an active Continuous Improvement Programme in place?	
	Please explain your answer to the question above	
	If you answered yes to the question above, please answer the following questions	
	Which of the following will fall within the scope of a CI programme	
1	Vision and Mission	☐
2	Idea Generation	☐
3	Problem Scoping and Definition	☐
4	Improvement Prioritisation	☐
5	Improvement Project Execution	☐
6	Improvement Project Tracking	☐
7	Improvement Project Close out	☐