The impact of Six Sigma on operational efficiency

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ABSTRACT

Globalisation of markets has brought about enormous challenges and opportunities for business organisations. The prevailing business environment propels organisations to improve and create value in order to remain competitive. Improvement and value creation begin internally and get reflected externally in the form of value added propositions to the market. Six Sigma is a methodology known for creating value within organisations, in all industries, through process improvement which translates into enormous savings for the organisation. Six Sigma is widely used globally and it has been in existence for many years, yet it is not so prevalent in the South African business environment. This research explores the principles and approach adopted, which distinguish the Six Sigma methodology from other improvement programs. In the manufacturing industry, operational efficiencies are essential to enhance value creation and profitability.

The study begins by discussing the origin, history and evolvement of Six Sigma into a methodology recognisable and espoused by leading world class organisations. The technique used to effect Six Sigma is entrenched and enforced by adherence to stipulated basic principles, breakthrough strategy and Six Sigma tools in identification and elimination of variation. The study later models some of Six Sigma tools by application on the operational entity in verification and testing of theoretical knowledge into practical knowledge that can be exploited for process improvement consequently enhancing operational efficiencies. The impact of Six Sigma on operational efficiencies underlie on the ability to positively change process effectiveness and capability to near perfection as expressed by defect rate of not more than 3.4 defects per million opportunities.

Key terms: Six sigma, operational efficiency, quality, operational improvement.

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ANOVA	-	Analysis of Variance
C & E	-	Cause-and-Effect
DFSS	-	Design for Six Sigma
DMAIC	-	Define-Measure-Analyse-Improve-Control cycle
DOE	-	Design for Experiments
DPMO	-	Defects per Million Opportunities
DPU	-	Defects per unit
Ě	-	Uncertainty/Variation
FMEA	-	Failure Mode Effects Analysis
FTY	-	First Time Yield
X	-	Predictor/Input
Y	-	Response variable/outcome/result
YTD	-	Year to date
Y=f(X)+Ě	-	Basic formula
Z-score	-	Sigma value/score
σ	-	sigma

CHAPTER 1
NATURE AND SCOPE OF THE STUDY

1.1 INTRODUCTION

Successful organisations focus on meeting customer requirements and process excellence to maintain and grow profitability. Evolving customer requirements are met by reviewing customer offerings to suit new customer requirements whereas process performance is mainly driven by meeting either the standards developed by the organisation, industry or world benchmarks. Kruger *et al.* (2006:27) assert that it is imperative for organisations to keep improving in order to align themselves with inputs from customers and their fast changing needs.

World-class companies strategically pursue customer focus and process excellence to maintain competitiveness. Most outstanding companies use Six Sigma to achieve these objectives. Schroeder (2004:168) highlights that Six Sigma is an approach used to improve both quality and net revenue of the organisation. Global competition and participation have prompted companies to adjust and master global practices to remain competitive. Six Sigma is attributed for producing impressive results among the world's leading organisations such as Motorola, General Electric, and Honeywell.

Six Sigma is a methodology employed by many leading organisations as a tool to manage and achieve continuous improvement objectives. Levine *et al*. (2008:737) state that many companies are using Six Sigma to improve efficiency, cut costs, eliminate defects and reduce product variations. The prevailing economic recession has led business organisations to experience declining sales and profits. This prompted most organisations to do introspection and initiate alternatives to minimise the impact of recession and keep the profits at acceptable levels. While some organisations closed shop, most organisations reviewed their internal processes and practices to derive value which would have a direct impact on their bottom line.

Processes and practices are under direct control of the organisation and therefore these should be leveraged to derive maximum value for the organisation. As much as organisations use processes like marketing intelligence to monitor outside forces that will impact on their competitiveness, from literature Six Sigma could be used to monitor and improve internal process and practices which should lead to process excellence. Davis et al. (2003:230) highlight that the managerial thrust of Six Sigma is based on providing a framework and techniques to analyse and assess business processes aiming to reduce waste.

1.2 PROBLEM STATEMENT

The cost of production is one of the key determinants of the organisation's competitiveness. Nowadays, the ability of the organisation to meet business needs is characterised by change, complexity, customer demands, and cost impact (Thawani, 2004:655). Putting it differently, Kanji (2008:577) stated modern organisations operated in a complex environment where low cost opportunities, rapidly expanding global markets, operational efficiencies and customer centric services determine the success of the business. Most of the companies that do not focus on cost are unable to compete effectively with global players because of the high cost structure. Evans and Collier (2007:124) state that competitive advantage is gained by many organisations by following a low cost strategy. They further assert that competitive advantage based on low cost is achieved by pursuing continuous improvement. It stands to reason that businesses operating with high costs are adversely impacting on the ability to be competitive.

The South African textile industry is a good example of this phenomenon. Despite producing good quality, the cost of production hinders them to compete effectively and maintain their market share. Giving insight into this situation, Correia *et al.* (2008:44) asserted that the South African textile industry has experienced severe competition directly from the import of textile but also indirectly from the import of clothing and apparel which reduces the demand for textile by local clothing manufacturers. Inability of the industry to match imported textile and clothing on price has weakened industry competitiveness.

This phenomenon also exists in other industries especially manufacturing. Most of these challenges emanate from process or operational inefficiencies and the lack of effective continuous improvement processes. According to Schroeder (2004:12), customer-directed operations do not forfeit efficiency in pursuit of meeting customer requirements. A customer-centric approach must be not only about customer satisfaction but it ought to be used as a driving force in pursuit of waste reduction and efficiency improvement objectives within the operation.

Operational efficiencies have a direct impact on the company's bottom-line. Efficient processes and continuous improvement processes have a positive impact on profitability of the organisation whereas inefficient processes have the opposite effect on profits. The recent economic meltdown highlighted the need for companies to be effective both internally and externally to sustain performance. Stevenson (2005:36) explained that operations contribute to organisation competitiveness through a number of factors including cost, quality and response time. Cost reduction can be leveraged internally to enhance profitability and competitiveness.

The organisation which will be used to conduct the analysis, based on some of the Six Sigma principles, is operating in the manufacturing industry. It is a dominant player in the local market and has some presence in export markets particularly in Asia and Australia. Competition in the local market is moderate. The local market consists of small to medium importers and foreign multinationals exporting products to South Africa. Competitive advantage is based on a low cost provider strategy and a broad differentiation strategy. The exchange rate is a critical variable in determining profit margin in the market. Appreciation of exchange rate promotes imports and flooding of products in the market by foreign multinationals which results in intensified competition. The depreciating exchange rate reduces imports and discourages multinationals to export which is a phenomenon that weakens competition.

The export market is characterised by opportunities currently driven by a trend towards production of renewable energy particularly bio-fuels. Price and product quality dictate competitive edge hence low cost provider and broad differentiation strategies are prevalent amongst competitors. Exchange rate appreciation reduces the profit margin and discourages exports whereas a depreciating exchange rate increases profit margin and promote exports. Organisations operating in such markets thrive to achieve low cost leadership to gain a competitive edge over rivals.

The objective of this study was to evaluate Six Sigma methodology in operational efficiencies improvement and entrenching continuous improvement and process excellence. Furthermore, it is to ascertain whether Six Sigma can benefit a typical manufacturing organisation in pursuit of process excellence.

1.3 RESEARCH OBJECTIVES

The research objectives are divided into general and specific objectives.

1.3.1 Primary objective

The primary objective of this study was to theoretically evaluate Six Sigma as an effective tool to improve operational efficiencies and promote continuous improvement and process excellence in manufacturing organisations.

1.3.2 Secondary objectives

The specific objectives of this study were:

- To research the benefits of Six Sigma.
- To ascertain whether the selected organisation will benefit from Six Sigma.

1.4 RESEARCH METHOD

This study, pertaining to the specific objectives, consists of two phases, namely a literature review and an empirical study.

1.4.1 Phase 1: Literature review

A literature review will be conducted using different sources. These sources will include journals, articles, books, magazines and the internet. The purpose for conducting such a review is to establish the understanding and insight on Six Sigma. This knowledge will be used to assess and draw conclusions on Six Sigma performance. The topics covered include:

- Six Sigma definition.
- Brief history.
- Methodology.
- Six Sigma tools.

1.4.2 Phase 2: Empirical study

The empirical study is based on monthly performance results of a milling organisation to evaluate a separation process using a number of basic Six Sigma tools.

1.4.2.1 Research design

The aim of the research design is to give a structure to the study. The study can be classified as descriptive and explorative. According Welman and Kruger (1999:19) descriptive research involves observing and describing the behaviour of the subject without influencing it whereas explorative research provides insight and comprehension of the subject. Explorative research will be used to research the topic.

The specific design used is a comparison test where year-on-year operations performance in terms of reported monthly yield for each process are analysed. Information gathered from the analysis will be evaluated against knowledge gained during the literature review. Expert knowledge is also required to have insight in making logical deductions.

1.4.2.2 Measuring instrument

Monthly process performance statements were used to determine the level of these processes in terms of Six Sigma benchmarks. A number of selected Six Sigma tools were applied to conduct an evaluation on separation processes.

1.5 LIMITATIONS OF THE STUDY

There are no limitations envisaged to conduct an evaluation on process performance.

1.6 CHAPTER DIVISION

The chapters in this mini-dissertation are presented as follows:

Chapter 1: Introduction and problem statement.

Chapter 2: Literature review.

Chapter 3: Empirical study.

Chapter 4: Conclusions and recommendations.

1.7 CHAPTER SUMMARY

Each chapter will be summarised highlighting different aspects discussed in the chapter. The purpose is to give an overview of the chapter to the reader.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

This chapter consists of the literature review conducted on Six Sigma. Various sources used to conduct the review include books, journals, articles and the internet. The purpose is to develop an understanding of Six Sigma and also to establish its application. The topics dealt with during the review include Six Sigma definition, its brief history, the methodology and the domain of activity. Six Sigma is utilized in different business sectors as an improvement process to enhance value and profitability.

2.2 SIX SIGMA DEFINITION

Six Sigma carries different definitions and meaning depending on the organisation's objective for its adoption and implementation. An array of objectives can be drawn from an organisation's business imperatives based on its performance and competitiveness. Depending on which business areas are selected and prioritised as Six Sigma projects, the definition is influenced by the value expected to be derived from such projects.

According to Schroeder (2004:167), senior management is responsible for selecting key processes which will support the implementation of the organisational strategy. This approach seems to bring sharp focus onto the desired value, making it a central theme throughout project execution, directing and aligning all actions towards the success of the project. Few definitions are considered from different organisations to illustrate this point.

It is a term originated from the Greek letter "sigma" which is used in statistics to measure variations in a process or set of data in order to denote the standard deviation within such a process or data. According to Evans and Collier (2007:649), the purpose of adopting Six Sigma is to have all critical processes to operate at a level of near zero defects. Defining Six Sigma, Evans and Collier (2007:649) refer to it as a business improvement approach that seeks to find and eliminate causes of defects in processes focusing on critical outputs to the customer and financial return.

Motorola defines Six Sigma as a robust business improvement methodology which propels an organisation to focus on customer requirements, process alignment, analytical rigour and timely execution (Motorola University, 2009). By focusing on customer requirements, Six Sigma compels the organisation to look into its customer offerings and adjust them accordingly as dictated by ever evolving customer requirements as influenced by the external environment. A focus on process alignment prompts the organisation to assess processes and practices internally and correct any deviations which contribute to misalignment. Both internal and external environments are constantly analysed so as to perfect customer offerings and process performance.

It is further defined as a data driven methodology designed to eliminate defects in any process, whether it is manufacturing and transactional in nature (iSix Sigma, 2009). The term refers to a program designed to reduce the occurrence of defects to achieve lower costs and improved customer satisfaction (Stevenson, 2005:400). On face value, Six Sigma is regarded as a quality improvement tool in a manufacturing environment since the manufacturing industry played a pivotal role in popularising the methodology. However, based on the definition an encompassing approach is illustrated in that it is looked upon as a tool applicable to all processes and all industries.

Barnes (2008:295) refers to Six Sigma as a management system which employs statistical techniques aiming to improve the capability of processes to the level of near perfection. Organisations use Six Sigma to enhance internal processes in order to improve the quality of products or services offered. Improvement in internal process is brought about by statistical analysis of real data from processes, identifying defects and implementing both corrective and preventive measures to enhance operational efficiency. Processes which deliver high operational or process efficiency are core to business sustainability and delivering of quality products or services. Davis et al. (2003:10) remarked that the overall goal of Six Sigma is to minimise waste from processes, consequently maximising value. Waste generated by process is indicative of inefficiency and it translates to losses.

For the purpose of this study, Six Sigma is defined as a methodology used by organisations to continuously improve quality and operational efficiency using statistics to analyse real process data in order to enhance their performance and profitability. From the definition, Six Sigma uses four pillars to distinguish itself from other improvement methodologies, namely quality excellence, process excellence, statistical process data analysis and financial gains.

2.3 BRIEF HISTORY

Carl Frederick Gauss (1777-1855) initiated the concept of the normal curve and Six Sigma can be implicitly traced to this concept. In the 1920s, based on the normal curve breakthrough, Six Sigma was used as a standard to measure variation in production. During that period, Walter Shewhart illustrated that to control a process, corrective measures should be taken when there are three sigmas from the mean. However, the term Six Sigma was popularised by Bill Smith who was an engineer at Motorola (iSix Sigma, 2009).

Reynard (2007:22) remarked that Smith discovered a process rate of failure is not caused by inherent design flaws but by accumulation of a lot of small defects made during the manufacturing process. Davis et al. (2003:145) agreed with this statement by pointing out that each activity or step in a company represents an opportunity for defects to occur. Smith, therefore, concluded that high quality can only be delivered by eliminating the source of defects and invented Six Sigma as a standard metric of quality. Motorola top management embraced and adopted Six Sigma and trademarked Six Sigma in 1987 (Reynard, 2007:22). In support of this new invention, it was of necessity to effect a cultural change to align norms and practices to a new way. A combination of the two brought significant improvement in Motorola's bottom line (iSix Sigma, 2009).

Following the success of Six Sigma methodology in Motorola, other industrial players began to show interest. Davis et al. (2003:231) highlighted that Honeywell implemented Six Sigma in 1994 and reported cost savings of more than $2 billion since implementation. According to Evans and Collier (2007:652), shortly thereafter in 1995, General Electric also implemented this methodology persuaded by Allied Signal and reported Six Sigma savings of $750 million in 1998.

Six Sigma developed into a transferable corporate management initiative and methodology used by the large manufacturing as well as non-manufacturing sector. Schroeder (2007:490) provides a list of adopters of Six Sigma revealing different types of organisation and sectors where Six Sigma is in use. The popularity of this methodology was further enhanced by openness of leading organisations and its proponents such as General Electric and Allied Signal in commending the benefits associated with utilising the methodology (iSix Sigma, 2009).

According to Gygi *et al.* (2005:15), Six Sigma has been recognised and adopted by the American Society for Quality and it became the global standard of quality business practice by 2005. Institutions of learning such as universities offer Six Sigma courses globally, whereas consulting and software companies are marketing and offering Six Sigma training.

Emphasis is placed currently on perfecting the breakthrough strategy in soliciting maximum value from Six Sigma. Breakthrough strategy is regarded as the critical path to a Six Sigma project success by re-creating the process or streamlining it for performance enhancement. Breakthrough strategy consists of management involvement, creating organisation structure which facilitates improvement, adopting a customer centric approach, opportunity analysis, extensive training and reward and recognition for successful problem solving (Metri, 2007:60).

2.4 METHODOLOGY

Six Sigma methodology is informed by two key elements to derive value and excellence from business processes. The fundamental principles underlying Six Sigma and its breakthrough strategy set it apart from other improvement methodologies. The two key elements are a premise on which Six Sigma thrives and these are attributable to its widely publicised success rate and its popularity. Stevenson (2002:429) remarked that the technical component of Six Sigma involves improving the process performance, reducing variation, utilising statistical methods, and designing a structured improvement strategy, which involves definition, measurement, analysis, improvement and control.

2.4.1 Basic principles

Six Sigma is based on basic principles which determine the unique approach to problem solving methodology and its effectiveness. These core principles provide a structured approach towards root cause identification, solution implementation and achievement of desired improvement. The principles are as listed below:

- Principle of Determinism.
- Principle of Cause and Effect.
- Principle of Variation.
- Principle of Measurement.
- Principle of Finding Leverage.

- **Determinism principle**

The principle is based on the general purpose equation, [Y=f(X)+Ě], which states that outputs are a function of work done on inputs. The principle focuses on the transformation process whereby inputs are transformed into desired outputs. There is some level of uncertainty inherent in the transformation process which is caused by elements such as process design, human mistakes or quality of inputs. These different factors need to be monitored and managed closely in order to deliver outputs at the desired standards.

This principle seeks to establish the understanding of relationships among inputs, transformation process and outputs by gathering valuable information about these elements. Proper understanding of these relationships will create an understanding of what elements are core in determining the quality of the output.

Furthermore, the determinism principle seeks to establish what parameters in the process determine the output. After establishing the determinants of output, these are controlled or manipulated to influence the output to give desired results. According to Gygi et al. (2005:30), Six Sigma effects this principle by analysing the inputs, the transformation process and the variation. The emphasis is on identifying all forms of relationships and related information that exist between inputs and the process in order to produce outputs.

- **Principle of cause and effect**

The thrust of this principle is on understanding the cause and effect in order to control the outcome. The aim is to establish the link between the cause and the effect. Cause and effect principle provides an understanding of the nature of relationships between inputs and the transformation process in creating the desired output. According to

Jacobs et al. (2005:30), Six Sigma create an understanding of the cause and effect relationships by testing hypothesis about relationships between process inputs and outputs. Establishing the understanding provides a base where results or outcomes are predicted, determined and controlled better. It increases the level of certainty in creating the desired or expected outcome.

According to Kruger et al. (2006:228), this principle presents various causes and effects in order to arrange them and identify different relationships which exist between variables. After establishing various relationships, it is essential to understand the influences present in those relationships. If such relationships are less understood, it is more difficult to determine and control the expected results hence there will be a high level of uncertainty as well as variation towards achieving the desired results.

The aim is to influence the transformation process and consequently the outcome by controlling these relationships. Knowledge of inputs, the transformation process, outcomes and the environment is core in deriving value applying this principle. More value will be derived if one is competent in the transformation processes and in applying the cause and effect principle on the process.

- **Principle of Variation**

Variation is defined simply as a deviation from expectation, according to Gygi et al. (2005:33). It is inherent during the processing or conversion of inputs into output. Stevenson (2005:436) asserts that all manufacturing or service processes display a certain amount of variation in its output. Variation is caused by combined influences of countless minor factors. Each factor on its own has a negligible impact on the process, thus elimination of such factor will result in insignificant improvement. The level of variation cannot be eliminated completely but it can be minimised. This principle seeks to establish an understanding of all forms of variations in order to implement measures which will smooth the process and consequently the outcome.

The two predominant variation types are called common and special variation. Common variation is caused by the natural factors in the process and hence it is inherent in the process. Evans and Collier (2007:690) explain common cause variation as a result of complex interactions of variations in materials, tools, machines, information, workers and environment. This type of variation occurs at random and its causes cannot be identified or explained.

A good illustration of this type is when comparing a new machine model to an old one. The variation exhibited by the old machine model is higher compared to the new model. In the new model, new design has engineered out most of the factors which are causing variation in the old model.

With special variation, specific factors which cause variation can be identified and it is normally accompanied by process instability. Evans and Collier (2007:690) assert that special case variation can be explained and understood because of its sporadic nature. Since specific factors can be identified, it means corrective measures can be taken to remove such factors from the process. According to Morgan (2005:33), it is better to work initially on reducing and eliminating special cause variation before embarking on initiatives to improve the process. Evans and Collier (2007:691) state it is easy to detect the special cause variation with statistical methods since these disturb the normal pattern of measurements.

Stevenson (2005:437) states that statistics can be used to identify and interpret variation using sample statistics which give sampling distribution depicting common variation. Levine et al. (2008:96) define variation as the dispersion or scattering of values away from a central value. Variation will therefore highlight the tendency of the actual output to adhere or lack of adherence to the desired output.

- **Principle of measurement**

Measurement is one of the core fundamentals in Six Sigma. Gygi et al. (2005:36) state that until one's knowledge includes measurement and numbers, one is bound to the world of gut-feel, guessing, and marginal improvement. On defining measurement, Thompson et al. (2005:36) referred to it as the practice of collecting data in order to establish underlying causes and the manner in which defects occur. Measurement involves gathering of data on the output, inputs, and the process.

Evans and Collier (2007:652) say this principle involves establishing how the process should be measured in order to determine how it is performing. Further to that, key internal processes critical to quality must be identified and defects generated in the process must be measured. The key to proper measurement is to decide upfront on the procedure to be used and also on the parameters to be measured. This allows consistency in collecting the data as well as the nature of the information required for better decision-making.

Morgan (2005:32) states that most organisations conduct measurement ineffectively despite the benefits of measuring properly. When it is done properly, it reveals the state or level of the process of performance and point out the underlying reasons thereof. Data is a source of information about a specific item, in this case inputs, process and outcome, which is useful in deriving conclusions leading to decision-making.

The data to be gathered is specifically chosen to highlight certain parameters which will reveal the insight regarding relationships that exist during conversion of inputs to outcomes. Choo et al. (2006:920) remarked that adopting a structured approach in solving problems helps in comprehending the problem and present the problem in a systematic way, leading to root causes being discovered and enhancing learning and knowledge creation. Continuous measuring, analysing and evaluation of data are imperative in improving the understanding of these relationships and a build up of expertise. Linderman et al. (2005:787) said Six Sigma use intentional or explicit learning to create knowledge through improvement methods.

Innovation and continuous improvement are enhanced as knowledge and proficiency are continually growing. The power of measuring is greatly unleashed with statistical analysis which package the data into information from which interpretations and inferences are made. It is from this base where corrective, innovating and improvement measures are derived.

- **Principle of finding leverage**

Finding leverage in Six Sigma is about identifying a few critical factors which bring about the greatest impact while processing inputs into outcomes. This principle dictates that a thorough analysis should be done on different relationships which are manifested during the execution of the general purpose equation with each element analysed in relation to other elements in the equation. The inputs are processed with a certain level of uncertainty to create outcomes. The sole purpose of leverage is to highlight few of these factors or variables with enormous effect in shaping inputs into outputs. Finding leverage is characterised by a systematic search and elimination of variables to achieve a critical few which bear greatest contribution. This then allows these factors to be critically monitored and controlled to influence and determined the desired outcomes.

The 80-20 rule or Pareto principle, commonly known as “the vital few versus the trivial many”, demonstrates this principle eloquently whereby

20% of inputs in the process are attributable to 80% of the influence on that process. In explaining the Pareto diagram, Levine et al. (2008:36) said the variables are identified with the “vital few” separated from the “trivial many” enabling one to focus on the important categories. The Pareto diagram is a powerful tool for prioritising improvement efforts where data consists of defective or nonconforming items.

Gygi *et al.* (2005:39) support this concept by stating that leverage in business is about searching for the minority parameters that solicit greatest impact in solving business problems. The scope, in this principle, concerns systematic identification of the critical few parameters from a horde of them rooted in the transformation process which are responsible for the greatest contribution in creation of outputs. An objective exercise must be undertaken to identify the sources of leverage by closely testing the deductions made from analysing data gathered on all elements of the transformation process including variation.

2.4.2 Breakthrough strategy

Breakthrough strategy is driven by both internal and external factors. Davis et al. (2003:230) view these factors as represented by the need for organisation to improve its processes capability in order to meet customer requirement consistently. Breakthrough strategy is triggered internally by need for organisation to improve inefficient processes whilst externally it is often prompted by changed customer requirements.

Breakthrough strategy employs a systematic and consistent approach in solving process problems. This method is known as DMAIC (Define-Measure-Analyze-Improve-Control), an improvement process focused on efficiency and effectiveness in business processes as stipulated by Gygi et al. (2005:41), with Jacobs et al. (2009:314) agreeing to that notion. Jacobs and Chase (2008:146) said breakthrough strategy use statistical tools in a systematic project oriented fashion throughout DMAIC phases.

The strategy focuses internally, aiming to unleash the strength and potential of the organisation inherent in its processes, practices, procedures and resources. Furthermore, it seeks to continually strengthen the organisation by employing new and better ways mainly initiated by internal innovation aiming at achieving near perfect processes and outputs. In Six Sigma language, internal process innovation is directed at achieving process defects of less than three on either side of the mean. All these efforts are undertaken to direct the organisational focus on understanding and achieving what the customer wants, according to Jacobs and Chase (2008:146), as this is a key factor in organisational profitability.

- **Define**

  The team begins the improvement initiative by defining process defects using measures that are critical to the customer (Schroeder, 2004:168). A Six Sigma methodology starts with the identification of the need for an improvement project. At the beginning of the project, a financial analysis is performed to quantify its expected financial savings and its impact on the bottom line (Salah & Carretero, 2009:239). Yung and Sang-Gyu (2007:56) agree that the DMAIC cycle starts with the problem in order to develop the scope of what needs to be done and to define the requirements of process improvement. It also includes setting a target for improvement. Business imperatives dictate which business areas need a focus for performance improvement. These areas are normally identified when the organisation reviews its monthly and yearly financial performance.

  The define phase sets the tone for the entire project by establishing goals, charter and infrastructure (De Feo & Bar-El, 2002:62). The criteria for selecting projects are based on the potential to offer breakthrough improvement. Such opportunities are evaluated against the strategic relevance focusing on creating value in areas such as operational efficiency, product and service quality which is greatly influenced by customer satisfaction or dissatisfaction, and bottom-line savings. Schroeder (2007:487) mentioned that implementing Six Sigma on existing processes, 3M aimed at making significant improvement in processes that were strategically selected by senior management.

Kanji (2008:576) stated that performance gaps need to be identified in order to set up a Six Sigma project. Monitoring the process forms a basis to identify areas which are not performing and factors causing non performance based on the factual information. This phase is directed at understanding the process and how it should deliver in order to identify clearly where the shortfall is.

On a monthly basis, performance gaps are identified during performance reviews and corrective plans are implemented to negate such gaps. However, performance gaps highlighted from the annual performance are treated as strategic imperatives going forward, hence Six Sigma features as strategic tool to realise the strategic objectives. The criteria for identifying and defining improvement business areas or projects are based on the highest financial impact. Salah and Carretero (2009:239) assert that expected financial savings are estimated based on an improvement target for a certain measure of the outcome of a process. The project that has a potential to yield the highest financial gains will be prioritised based on this outcome while lower potential projects will be less considered.

When the project is defined, it should clearly indicate what it seeks to resolve and achieve for the business. This definition should be expressed and translated into financial performance and gains. Kew et al. (2006:491) say one of the first tasks in business is to set financial goals. Goal or target setting is an essential part in the planning process. It is imperative that projects or improvement initiatives assigned to the Six Sigma process have goals that can be easily translated into financial performance.

- **Measure**

After defining an improvement area to be pursued and setting the target to be achieved, measurement is phased in to determine the level of achievement against the set target. This is a continuous process which is used to gather sufficient data or information about an improvement area in order to highlight progress or lack of progress towards achievement of the set goal or target. According to Morgan (2005:32) measurement gives the level in which the process is performing and also alludes to some of the reasons underlying lack of performance. Information gathered is used to validate the problem and ascertain that the problem is worth solving.

The measure phase is concerned with identifying key customers and determining critical to quality requirements necessary for a successfully designed product, service or process (De Feo & Bar-El, 2002:62).

Morgan (2005:32) states that measuring is an essential task within the organisation and yet it is not often carried out effectively by most of organisation. Measurement is the foundation of knowledge and subsequent improvement. It reveals the current level of performance or status of the process and different interrelations existing and influencing the process outcome. Measuring will indicate whether there is conformance, improvement or decline when compared to the limit or expectation and the outcome resulting from such comparison will determine trigger the next step to be followed. According to Kew et al. (2006:492), a measurement will only be meaningful when it is compared with another measurement. Comparative measures are required to conduct comparison. The actual performance can be compared to the previous level or a set target.

Conformance is indicative of the maintenance of the status quo and as such the benefits remain unchanged. Improvement indicates a positive progress against the limit, thus the performance exceeds the laid down standard or expectation and more benefits are experienced by the business. A declining performance signals weakness in the ability to meeting the set limit or expectation, therefore the business experiences reduced benefits translating to losses. Kew et al. (2006:491) said after setting targets, the actual performance is measured and assessed against these targets. Data are collected on these measures to establish the current process baseline and goals for improvement (Schroeder, 2004:168).

Organisational performance is measured extensively in its financial management function. It is not only measured, it is analysed and interpreted in order to make informed decisions. Financial statements are instruments used to measure different aspects of the financial management function whereas financial ratios are used in analysis and interpretation of the measured aspects. The emphasis of these measures is to compare current performance with the previous one or comparing the organisation with similar ones. Six Sigma is extending a similar concept to all functions and processes within the organisation emphasizing eradication of process defects, process improvement, and to create near perfect processes solely to enhance organisation performance.

Schroeder (2004:164) stated that the ability of the process to meet or exceed its specification is a key aspect in continuous improvement. The process capability signifies process effectiveness to deliver to specification (Jacobs et al., 2009:331). This is a measure of the ability of the process to meet the specification and measurement facilitates comparison of the process output to specification. Measuring performance gaps and process capability is fundamental in Six Sigma to guarantee success in executing improvement objectives. Emphasis is placed on identifying performance gaps that exist between current performance and targeted performance. The current performance of a process is measured and analysed for critical causes or variations that hinder target performance to be achieved. Performance gaps are corrected by altering existing conditions impacting on the current level of performance. Suitable solutions are then generated and implemented to eliminate root causes in order to correct and improve the level of performance.

Process capability measurement aims to determine the fit between process performance and customer satisfaction. It seeks to determine how well the process performance meets customers' expectations. According to Gygi et al. (2005:123), process capability is the effect of the relationship between the voice of the process and the voice of the customer, and how well the two match each other. In measuring capability, a comparison is conducted based on process performance in relation to process requirements. Stevenson (2005:452) says processes must be evaluated to determine whether they are capable of meeting specifications. If a process is not capable of meeting the specification, a decision must be made on how to correct the situation. For any differences which are identified, a clear course of action is drawn and implemented to remove such variation and improve performance to the required or expected level.

Determinants of customer expectation are spelt out in specifications which the process must meet. In their definition, Jacobs et al. (2009:330) define specification as the target value and the limits acceptable for the target value, alluding that performance on target or/and within specified limits is acceptable. Specification is defined by two limits: the lower and upper limits. Any performance which is within the two limits is deemed satisfactory while outside the limits performance is said to be unsatisfactory. Acceptable performance meets customer expectation as opposed to unacceptable performance which results in an unsatisfied customer.

Six Sigma introduces target performance as a unique approach to improve performance and reduce costs. The focus is to get the process to perform on target with as little variations as possible. An improvement is attained when a process achieves the target and the variations are reduced continuously to a near perfect process. A process which misses the target with wide variations is costly, under achieving and usually referred to as out of control with minimum chances of meeting customer expectations.

According to Kew *et al*. (2006:491), after measuring performance and assessing it against targets, a determination will be made on whether goals were met or not. When specific goals have not been achieved, corrective actions must be planned and implemented to bring actual results back in alignment with expectations. According Stevenson (2005:4) to ensure that the desired outputs are obtained, measurements must be taken at various points in the transformation process, and then compared with previously established standards to determine whether corrective action is needed.

- **Analyse**

All gathered information, from the measuring phase, is evaluated to highlight the nature of performance trends developing towards the target. The tracking of performance through data analysis is a key element in guiding the decision-making process towards achievement of the set target. Analysis consists of thinking about, pondering over, and probing recorded data in order to enhance understanding. Six Sigma employs statistical methods to analyse and interpret data. The prime objective of data analysis is to identify a few critical factors which have a great impact on performance from many factors highlighted by the gathered data.

Data are used to understand what happened in the past, to interpret the current situation and predict performance in the future. Data-driven decision-making characterises Six Sigma culture. Decisions are informed by deductions and conclusions derived from the data analysis and interpretation using Six Sigma tools. Six Sigma tools are used to identify and narrow down the number of factors which have a direct impact on process performance. Evans and Collier (2007:652) point out that analysing creates understanding of reasons why defects are generated by identifying the key variables that are most likely to create process variation. According to Thomson and Lewis (2002:20), Six Sigma team uses data to investigate process areas which display inconsistency and conduct root cause analysis to determine underlying factors.

The recipe for success in improvement begins with measuring and recording as many factors as possible in the process. During analysis, using Six Sigma tools, factors which are not critical are eliminated and those that are critical in directly influencing performance are retained. The purpose is to identify the potential variables which influence a critical outcome. Apart from establishing critical inputs to the output, analysis seeks to determine the nature of the relationship existing between them.

- **Improve**

The improvement phase focuses on the workings of the system or process to effect improvements. In Six Sigma terminology, a defect is any mistake or error that is passed on to the customer (Evans & Collier, 2007:650). Defective process outputs generate waste or material that needs to be reworked or reprocessed. In both cases, the process effectiveness is adversely affected, resulting in lowering of process efficiency. Process effectiveness and process efficiency display a direct relationship where a high effective process will result in improved process efficiency. Six Sigma aims to improve process effectiveness.

This phase is based on examining the nature of the relationships of chosen critical inputs to the output; understanding and influencing them to consistently produce the required output. The purpose is to enhance the knowledge and insight about the process in order to build capacity to predict the output consistently. In summarising an improvement phase, Gygi *et al.* (2005:195) stated that it is a point where improvements are created and systems or processes are reshaped to perform better. Systems or process performance is enhanced by reducing variations, elimination of performance gaps, to the minimum as well as improving process capability, resulting in customer satisfaction.

The team seeks to determine the root causes of the current defect levels. This involves looking beyond the symptoms and finding the real causes (Schroeder, 2004:168). Statistical quality engineering is a key component in a Six Sigma programme which will determine the success of deployment during the improvement phase (Kruger *et al.*, 2006:266). Specific tools are offered by Six Sigma to pursue the improvement objective depending on the complexity of the process. Design of Experiments (DOE) is the most commonly used tool which endeavours to establish an understanding of a system or process to have an insight on how to function and that knowledge will help to create initiatives that will bring about successful improvements. Jacobs *et al.* (2009:318) outlined that in Six Sigma, experiments are used to determine and understand the relational foundation between the inputs and outputs by observing the following:

- **Knowing which inputs have significant effect on the output and which inputs are insignificant.**

Inputs are core determinants of outputs during the transformation process. These have a direct link to the output and direct proportional relationship with outputs. Stevenson (2005:4) highlighted that the process of transforming or converting inputs into outputs leads to the provision of goods and services. A number of inputs are used in the process to produce the output; often these are classified according to the impact it has in determining the output. Inputs which have significant impact on the outputs are often called direct inputs. These are attributable to the form and quality of process output and without it the output cannot be produced. These contribute significant costs towards manufacturing costs. The costs are unavoidable as it plays a direct role in the production of output.

Process inputs with less or insignificant impact are often referred to as indirect inputs. The latter have a minimal role in determining the form or quality of the outputs. In most cases, the output can be produced without using them. The role of indirect inputs can be regarded as a means to fine-tune the outputs and sometimes this role is regarded as cosmetic. When production costs are revised, indirect inputs are the first to be considered for a cost-cutting exercise.

One of the first tasks in the Six Sigma improvement process is to establish the understanding and develop the knowledge of the process or system under review. It is regarded as a precondition to understand the fundamentals of the process in order to effect desired improvement. The two Six Sigma principles which are used to establish this understanding and knowledge are the principle of determinism as well as the principle of cause and effect. The principle of determinism seeks to establish the understanding of all relationships existing between inputs and output during the transformation process. Identification of all building blocks are established without attaching any measure of importance to them; all inputs going into the transformation process are well considered.

The nature of the relationship between inputs and outputs including the process is evaluated through the principle of cause and effect. This evaluation highlights which inputs are the main contributors towards the creation of the output and which inputs contribute less to the output.

- **Formulating and quantifying the mathematical relationship between critical inputs and the output.**

  Stevenson (2005:4) mentioned that desired outputs are obtained by taking measurements at different points during the conversion process and also taking corrective action after comparing these measurements with previously established standards. Measurements serve as feedback on how the transformation process is performing against the set standard, giving an indication of how much of each input is consumed to form the output. Emphasis is put on critical parameters which have a significant impact on the output.

  Evans and Collier (2007:662) said applying the Pareto analysis will help in separating the vital few from the trivial many and provides direction on which variables to focus on. Six Sigma's principle of finding leverage is central at determining critical inputs. As discussed under this principle, the determining factor in deciding critical inputs is the latter's significance in influencing the outcome. Stevenson (2005:15) says, "It is axiomatic that a relatively few factors are often most important, so that dealing with those factors will generally have a disproportionately large impact on the results achieved".

- **Statistical verification that a process improvement has been made.**

  According to Stevenson (2005:452), capability analysis is conducted on the process to compare variation inherent in the output to the variation allowed by the design specification and whether the variability is acceptable. Measuring real data and analysing such data is of the utmost importance in the verification process. Statistical analysis is one of the hallmarks of Six Sigma to the extent that there is a special category of statistical tools which is used to analyse and convert data into useful information.

Analysis is based on real or factual data gathered from the process or system. Information generated from analysing data will therefore depict the actual status of the process or system, whether it meets set standards or it needs to be improved. A decision to improve will involve precise areas that need improvement and the corrective action which will bring about the improvement and tracking progress as action is taken. Tracking progress also involves measuring and interpreting the actual performance and comparing it with targeted performance. The level of performance is quantified statistically to determine the level of progress made which is translated into improvement achieved. Statistical analysis tools are primarily used to determine whether the improvement has been achieved or not.

- **Establishing values of critical inputs which will optimise the value of the output.**

The principle of finding leverage is core at establishing which inputs are critical during the transformation process in determining the output. It further looks at the extent to which each critical input contributes towards the output. This is valuable information as it relates the quantities of each input in relation to quantity produced. The desired quality of the output will dictate the amount of each input required to achieve this purpose.

After conducting the experiments and establishing good understanding and knowledge of the process or system, the operational focus changes from passively monitoring the output to actively monitoring, and influencing critical inputs to produce a desired output (Gygi et al., 2005:198). The insight gained on the process by experimenting leads the approach in monitoring the process or system to focus on proactive prediction as opposed to reactive correction.

- **Control**

The control phase focuses on sustaining improved performance of the system or process. Without control, there is a risk of fluctuation in performance, but of high concern is the possibility of performance declining to levels that were experienced before improvements had been introduced to the process. According to Fitzsimmons and Fitzsimmons (2008:157), the role of the control phase is to develop systems which will control the improved process.

Just like in the previous phases, Six Sigma affects the control phase through tools and techniques which ensure that the improved performance is sustained. This phase involves putting tools in place to ensure that the key variables remain within the maximum acceptance ranges under a modified process (Jacobs & Chase, 2008:146). Kruger *et al.* (2006:105) say control relates to measuring outputs and comparing it to predetermined standards. Any serious deviation from the set standard must be rectified as speedily as possible.

The performance is monitored and the achievement is proven by the end of the project based on the data on hand (Salah & Carretero, 2009:239). Performance monitoring involves continuous measurement and establishment of the trends depicting performance in relation to a set or desired outcome. Necessary adjustments are thus made continually so as to remain on track with the improvement objective.

2.5 TOOLS

Six Sigma utilises tools and techniques in a structured data-driven method to enable companies to measure its performance both before and after Six Sigma projects. Linderman *et al.* (2002:198) stated that Six Sigma organisations employ problem solving tools and structured improvement methods based on scientific method. This comprehensive methodology takes complex tasks and simplifies them into components, which can be easily understood.

According to Jacobs *et al.* (2009:315), tools used in Six Sigma have been used for many years in traditional quality improvement programs and this assertion is supported by Barnes (2008:298). A unique approach has been developed in Six Sigma in the application of these tools by integrating it in a corporate wide management system (Jacobs & Chase, 2008:146). The approach employed in Six Sigma is based on principles, tools and techniques that were developed and have existed long before this methodology became well known. What sets Six Sigma apart from other improvement concepts is its unique approach of integrating and translating these principles, tools and techniques into best practices.

By using traditional tools, Six Sigma used the existing knowledge differently to achieve the same improvement objective which was pursued by other improvement processes. Therefore, Six Sigma was not a completely new entity when it was introduced except that the methodology was uniquely structured in the way these tools were applied at different stages or phases of the improvement process by introducing a systematic and consistent approach. For these reasons, Six Sigma became relevant immediately on its introduction to organisations seeking to improve its processes.

Six Sigma makes use of an array of tools available to be utilised at different phases of the improvement process; however, it is not prescriptive on which tools to be applied. The prerogative remains with the user depending on the nature of the process. Six Sigma tools are categorised into process optimisation and statistical analysis tools. Classification of Six Sigma tools seeks to meet different requirements of the improvement to effect change successfully.

Data collection and data analysis are prerequisites to arrive at informed decisions during Six Sigma process implementation. Gygi et al. (2005:245) described process optimisation tools as primary tools utilised to identify causes of process or system ineffectiveness, inefficiency, variation and waste. The primary role is in collecting data to create an understanding of how work is performed and identify root causes for underperformance. Optimisation tools facilitate the design, simulation and optimisation of processes or systems.

Table 2.1: Process optimisation tools

Tool	Role
The SIPOC	Suppliers-Inputs-Process-Outputs-Customers. Create a high level process map with a few key details about each of the key contributing elements.
CT (critical to) tree	Critical to tree. Identify, organise and display parts of the process according to areas of critical importance.
Modelling	Define and design processes, including the flow of work or material, the timing of activities, resources consumed and points of decision, inspection and delivery.

Table 2.1: Process optimisation tools (continued)

Simulation	Simulate the flow of work and material through a process based on the model, and analyse the results of the simulation for overall effectiveness and efficiency. Find defects, errors, bottlenecks, variation and non value-added elements.
C&E (cause-and-effect) matrix	For the outcome of any process, define all the contributors, weigh their effects and determine the significant contributors to the outputs.
Fishbone diagram	Create a high-level C&E in the form of a tree structure, with categories for each major type of contributor. A method for capturing potential causes and inputs to a process.
FMEA (failure made effects analysis)	For any activity or item, define the potential failure modes, including the likelihood of occurrence and the ability to detect and characterise the effects of those failures.
Capability and complexity analysis	Analyse the tradeoffs between product complexity and process capability and define the proper configuration of each to achieve desired outcomes.
Plans	Use the outputs of simulation and analysis to define how data will be collected and how the processes will be controlled and audited.

The second category of Six Sigma tools comprised statistical analysis tools solely to analyse real data collected either from process, simulation or experimental exercises. Data sourced utilising process optimisation tools are analysed and converted into useful information to enable informed decision-making.

Statistical analysis tools are one of the major distinguishing features of Six Sigma compared to other improvement processes. They provide interpretation and give meaning of the available data by converting data into useful information. Measurements and interpretation of data are hallmarks of this methodology. Also in this category of tools, traditional statistical tools are used.

Table 2.2: Six Sigma statistical analysis tools

Tool	Role
Basic statistics	The basic and descriptive statistics, such as averages, ranges, variance, and so on, used routinely in Six Sigma analysis.
Plots and charts	Histograms, Pareto charts, control charts.
Time series	Specific tools for analysing results of data collected over time – trends, decomposition, moving averages
ANOVA (analysis of variance)	Analyse variances, test for equality of variances and determine whether there is a valid relationship between variables.
Tolerance analysis	The analysis of margins and tolerances to determine optimal design specifications.
DOE (Design of Experiments)	Systematically investigate the process or product variables that affect product quality.
Process capability analysis	Determination of the capability of a process to perform to expectations. The output is a numerically defined index of capability.
Regression	Determining the strength of the relationship between a response variable (Y) and one or more predictors (Xs).
Multivariate analysis	The analysis of data from multiple measurements on various items or subjects. The output is a graphical picture of the various relationships.

Table 2.2: Six Sigma statistical analysis tools (continued)

Exploratory analysis	Methods used to explore data before applying more traditional statistical analysis tools.
Measurement system analysis	The analysis of the measurement system to determine the accuracy and precision of the data obtained from the measurement.
Reliability and survivability	Accelerated life testing, lifetime characteristics analysis, growth curves.

Salah and Carretero (2009:239) assert that Six Sigma tools are utilised to achieve a high level of consistency in product quality, processes or systems performance. This array of tools provides Six Sigma with a flexibility which encourages its application to be relevant to different industries, processes and systems. The assertion that the methodology can be used successfully in any application affirms this flexibility. According to Dasgupta (2003:356), Six Sigma metric enables comparison of performance of any two processes despite their nature.

Key to the classification of improvement tools is the provision of data, enhancement of knowledge and understanding of the problem at hand in order to make informed decisions in pursuit of the elimination of root causes of the problem. Among sources of data listed by Levine et al. (2008:6) relevant to Six Sigma are designed experiment and observational study. Information derived from data increases process understanding and knowledge such that the workings and behaviour of a particular process and its parameters can be predicted. With increasing insight on the process, changes are introduced until a near seamless operation is achieved.

Linderman *et al*. (2002:198) stated that several Six Sigma organisations use computerised tracking software which monitors the steps and tools used in the improvement project. These types of mechanisms promote the proper application of the tools and methods that help reduce task complexity.

Statistical tools are perceived to be complex and that they require special skills in order to apply them. Technology has always provided simplified solutions to problems, and statistical tools application is not exempted. Software packages which have simplified the application of these tools are readily available and can be used to maximise value from improvement initiatives.

Process optimisation tools together with statistical analysis tools are technical skills which Six Sigma practitioners require to successfully bring improvement by utilising Six Sigma methodology. The tools are applied on the improvement project and are intended to have a specific outcome in all phases of the process. These are somehow specialist skills which must be mastered by the practitioner in order to ascertain the success of Six Sigma application.

In addition to the two groups of tools, Six Sigma requires the improvement project to be properly coordinated and managed. The tools required for this purpose are referred to as Six Sigma management tools. Unlike technical tools which are applied on the process, management tools are required to facilitate the interaction between the practitioner and other stakeholders in pursuing the improvement objective.

Six Sigma management tools support each of the constituents, those participating in the project and those supportive of the project (Gygi *et al.* 2005:284). For a practitioner, management tools are helpful towards managing expectations, inducing cooperation and dealing with dissenters, to ascertain that an improvement project succeeds. Any initiative which is not inclusive, where only a select few participate, often gets opposed and not fully supported within the organisation.

To change this kind of a mindset, it is imperative that Six Sigma practitioners do not only rely on the good intent of methodology to bring improvement and savings as a selling tool but they also need to acquire skills which will help them to market this methodology properly. Those who are willing to participate must be encouraged and propelled to not only contribute fully but to be advocates as well.

It is for these reasons that a practitioner must also possess management tools. Management tools are often common for most of the functions within the organisation which require management; therefore, management skills learnt will be applicable to both Six Sigma and general management purposes. The practitioner should not only possess technical and industry specific expertise but he/she should also be a generalist.

Table 2.3: Six Sigma management tools

Tool	Role
Communication and leadership	Both communication and leadership tools are both formal and informal. Company Intranet sites, video messages, letters and memos, reports and other messages.
Project management	Management tools include everything from capturing ideas into project assignments, staffing, budget and performance. The more advanced tools include multi project and cross project portfolio management in shared enterprise culture.
Reporting tools	These are tools that query data and create reports; provide standards and reputable ways to communicate detailed information. These reports include tables, plots and charts of analytical and performance data. These are combined with budgets, resources and business-impact information to create comprehensive pictures of project and program status, progress and trends. When aggregated, these tools are typically called dashboard.

Table 2.3: Six Sigma management tools (continued)

Knowledge management tools	These tools are extensive collaboration tools, granting individuals and teams access to information repositories. By having access to the right knowledge at the right time, managers and practitioners can expedite return on the improvement investment.
Learning tools	Beyond traditional training, learning tools provide direct, just-in-time, and low-cost training to individuals, teams and companies. These tools are critical enablers for the job of training large numbers of people in concepts, ways and methods of Six Sigma.

2.6 DOMAINS OF ACTIVITY

The application of Six Sigma requires to be effected in four areas within the organisation. The areas or domains include thinking, processing, designing, and managing. Domains of thinking and managing are not as predominant when compared to domains of processing and design in discussions relating to Six Sigma. It is very easy to conclude that Six Sigma only focuses on the two domains and yet all four are imperative.

2.6.1 Thinking for breakthrough

Thinking for breakthrough is based on the underlying basic principles of Six Sigma. A methodology of Six Sigma provides a systematic and structured approach to deal with process variation and defects. To implement these procedures and guidelines, people are required to be aligned to ways which will bring improvements that are advocated by Six Sigma.

Linderman *et al.* (2002:198) state that Six Sigma organisations also provide extensive training to ensure proper use and understanding of the methodology. The training format ensures that participants not only understand concepts of Six Sigma (declarative knowledge), but also to understand how to apply these concepts (procedural knowledge). The motive is to change the prevailing mindset to the one that will support the Six Sigma way of thinking. This domain deals with changing the existing culture of the organisation.

Kull and Wacker (2009:234) remarked that improvement initiatives like Six Sigma require a culture which promotes predictability with elements of future orientation and institutional collectivism. The two cultural elements encompass strategic thinking as well as group thinking to induce approaches that elicit long term objectives and synergy. Introduction of change rattles comfort zones which normally result in resistance to such change. It is of utmost importance to solicit cooperation from all constituents for the intended change to succeed. In Six Sigma projects, a variety of practices may be used to capture explicit and tacit knowledge of team members for achieving specific project goals (Anand *et al*., 2009:305).

This domain not only instils new thinking but it also seeks to solicit active participation by every employee to entrench the new culture in the organisation. Thompson et al. (2010:365) argue that the statistical thinking process used in Six Sigma is informed by three principles that all work as a process; all processes have variability and all processes create data that explain variability. In this domain, application of both tacit and explicit knowledge is critical to implement these principles. An added advantage, resulting from applying the principles, is the learning experienced by personnel involved which gives them insight leading to expertise into the process and sharpening of their skills.

2.6.2 Processing for breakthrough

This domain focuses on process optimisation, targeting process excellence. It is the centre of execution of plans to improve the process to perform at higher levels. Optimisation is directed at determining process parameters and conditions that will drive the performance to the best capability of a process or to enable the process to perform at optimum levels. Moving a process performance from any lower level to optimum level will bring an improvement in performance which is what Six Sigma approach is all about. Action plans are implemented to move the process performance level towards levels stipulated by Six Sigma methodology.

The aim of Six Sigma is to improve processes to near perfection and this purpose is achieved in the domain of processing for breakthrough. Solutions tailored to resolve performance inhibiting factors are directed at correcting and preventing recurrence to sustain improved performance. The emphasis is on elimination of the root causes in order to achieve a sustained and reliable improved performance which is referred to as breakthrough improvement.

2.6.3 Designing for breakthrough

The domain focuses on the design of processes, aiming at creating near perfect processes. A specific approach relating to designing is provided in the methodology and is referred to as Design for Six Sigma (DFSS). DFSS gives the organisation an ability to detect and prevent defects when designing or modifying a process to create the process that can achieve high Sigma level (De Feo & Bar-El, 2002:62). Designing for Six Sigma aims at building in efficiency in the process during design phase. The efficiency from the process is targeted to match Six Sigma performance levels where wastage is at minimal levels.

2.6.4 Managing for breakthrough

Managing for breakthrough entails all the plans, systems, and processes for leading a Six Sigma deployment and implementing it in an organisation. This is the mechanism by which an organisation drives and supports the activities in the domains of thinking, processing, and designing for breakthrough (Gygi et al., 2005:45). The management component involves providing strong leadership, defining performance matrices, selecting projects likely to achieve business results, and selecting and training appropriate people (Stevenson, 2009:429).

The domain of managing provides elements of both general management functions and leadership aiming at obtaining synergy within the organisation. According to Evans and Collier (2007:653), diversity of skills is essential for managing a Six Sigma project successfully. The skills variety ranges from technical analysis, creative solution, development and implementation. As Six Sigma takes hold across the organisation, it creates an internal infrastructure that includes all staff levels in the organisation. Evans and Collier (2007:653) emphasise that managing a Six Sigma programme is not only about process improvement but it is also about creating a learning environment, management development and career advancement for individuals.

Six Sigma is not simply another supplement to an organisation's existing management methods. It is a complementary management methodology that is integrated into other facets of the business. It affects all areas of the business including how the organisation is managed, integrating processes and personnel at different levels with the purpose of bringing positive change within the organisation.

Goh *et al.* (2003:754) remarked that a Six Sigma programme requires top management's active participation and an organisational culture change. Six Sigma will succeed in any organisation if there is buy-in at the top. Top management must lead the deployment after formulating and communicating the company's Six Sigma objectives through all levels of the organisation. According to Metri (2007:60), one aspect of Six Sigma implementation requires top management to take initiatives whilst middle management should create an environment that will support adaptation and entrenchment Six Sigma methodology. Management at each level has a critical role to play to bring about success and benefits of Six Sigma within the organisation.

Other key players in a Six Sigma program are Master Black Belt, Black Belts and Green Belts. Champions strategically identify and rank potential projects, help select and evaluate candidates, manage program resources, and serve as advocates of the program. Master Black Belts are trained extensively in statistics and use of quality tools. They teach and mentor Black Belts. Black Belts are project team leaders responsible for implementing process improvement projects. Green belts are members of the team (Stevenson, 2009:429).

2.7 VARIATION

Defining variation Gygi *et al.* (2005:33) describe variation as deviation from expectation. Stating variation differently, Levine et al. (2008:96) argued it is the tendency of values to disperse or scatter away from a central value. The presence of variation in the process shifts actual performance away from expected performance by creating output which is not meeting process requirements. The magnitude of variation in the performance of the process is fundamental in determining how far a particular process output deviates from expected or required results. The process, which displays high variation, deviates from expectation or specification and as a result it diminishes the ability to consistently produce as expected. The philosophy of Six Sigma is based on reducing variation to bare minimum in processes in order to improve their capabilities.

In describing the benefits of Six Sigma, Jacobs and Chase (2008:156) say the performance of the process is described in terms of its variability and it allows comparison of different processes using a common metric. Process performance is evaluated in terms of its success and failure rate. The norm is to focus on the success rate; however, the parlance in Six Sigma emphasizes non compliance or failure rate in order to compel immediate corrective measures to be taken. Fitzsimmons and Fitzsimmons (2008:157) remarked that the approach used in Six Sigma to report errors or failure rate is more motivating than reporting performance using success rate. Through failure we can discover the true reflection of what processes are capable of and the reality will prompt actions to reduce the failure rate. Non compliance has a direct impact on effectiveness of the process and its success rate.

A process generating a high percentage of non compliance operates at low levels of effectiveness and success rate. Failure creates the impression of under performing irrespective of its percentage, whether it is high or low and there is no business organisation which associates and identifies itself by failure rate. Undertaking this approach organisations are thus compelled to take initiatives that will reduce non compliance or failure rate in their processes, and in so doing impacting positive on process effectiveness and efficiency.

Fitzsimmons and Fitzsimmons (2008:156) remarked that tendency of organisations to use averages to measure their performances ignores variation in their results and therefore hides existing problems, pose serious questions on how performance is measured. Such measures fail to highlight performance impeding factors, promote ignorance to remove performance constraints and obscure opportunities available for improvement. Organisations reporting their performance in averages are easily misinformed about their actual capability; they have self inflicting pain tendencies in that decisions made are not maximising the potential of the organisation.

The Six Sigma premise is based on a general equation stating there is always some level of uncertainty or variation in converting input into desired output, asserting that variation is an integral part in all processes.

$$Y = f(X) + Ě$$

where:

- Y - outcome or result
- F - transformation process or function of the input
- X - input
- Ě - uncertainty or variation

As stated at the beginning of the chapter, variation is inherent in every process and it limits processes to achieve perfection. If left unchecked variation disables a process; as a result, uniformed and misleading decisions are likely to be made. Variation is resultant of error, either from the process, human or a combination of the two. Six Sigma seeks to eliminate or reduce variation from processes to achieve a near perfection state. Describing this state in Six Sigma terms means each process must not exceed 3.4 defects in a million opportunities.

It is therefore imperative, in this approach, to understand how variation is manifested and its impact on the outcome. Six Sigma endeavours to eliminate special cause variation, and reduce common cause variation to levels that are predictable. At such levels of variability, the output from the process can be predicted as well with much more certainty.

As an imperative in Six Sigma, measuring is essential in understanding any scenario which needs to be dealt with. Measuring variation actively is such a significant part in Six Sigma because it carries uncertainty which highly influences the failure rate in the process. Against this backdrop, process improvement in effectiveness and efficiency cannot be realised if causes of variation are unknown and are left unattended. Dasgupta (2003:356) listed some of the commonly used metrics in Six Sigma to measure variation:

- DPMO – defects per million opportunities
- DPU – defects per unit
- Z-score or Sigma value
- Throughput or Sigma yield

These metrics are closely correlated and referred to as standard Six Sigma metrics, applicable to all processes undergoing Six Sigma improvement.

2.8 CHAPTER SUMMARY

Six Sigma is used in different industries ranging from manufacturing to transactional processes. Therefore, its definition is derived from the purpose for implementation and the objectives to be achieved. Six Sigma was pioneered by Motorola through integration of different traditional improvement programs and techniques by structuring these programs into a sequential methodology. Fundamentals of Six Sigma comprised of, amongst others, basic principles and breakthrough strategy. Basic principles articulate the approach adopted in Six Sigma whilst breakthrough strategy is a mechanism applied in executing basic principles.

An array of tools is employed in Six Sigma and are categorised into optimisation, statistical analysis and management tools. These tools are utilised in each phase of Six Sigma process to gather data for analysis and decision making. Data gathering and statistical analysis are hallmarks in effecting Six Sigma. The premise in Six Sigma is that each process has inherent variation and therefore it seeks to reduce or eliminate variation displayed by processes. Variation inhibits the effectiveness in processes and causes unpredictability in process performance and outcome. Through reduction or elimination of variation, Six Sigma improves process performance characterised by high levels of effectiveness and efficiency.

CHAPTER 3
EMPIRICAL STUDY

3.1 INTRODUCTION

The concept of Six Sigma is synonymous with process improvement and cost savings. This methodology is applicable to all business processes hence it is utilised in different industries to derive value for business organisations. One of the imperatives of Six Sigma is to assess each process to determine its effectiveness or its base of performance before any improvement initiatives are undertaken. Chapter 3 assesses four processes of a milling organisation to establish the level of effectiveness using some Six Sigma tools.

Results reported for the period 2006 to 2010 were used and analysed applying Six Sigma principles. The aim was to establish how current processes perform, to establish at which level of Sigma are they operating and whether there is an opportunity for improvement as well as determining whether operational efficiency will be impacted if Six Sigma approach is adopted. Levine *et al*. (2008:737) state that Six Sigma programs focus on processes to increase efficiency, reduce variability, reduce costs and eliminate defects. This assertion implies that an organisation which employs Six Sigma initiatives is empowered to improve operational efficiency if it has the intention to focus on understanding and implementing measures to reduce variation in processes. Evaluation of processes is covered under the following aspects:

- Defects Rate
- Sigma Yield
- Sigma Level
- Process Capability

3.2 BRIEF DESCRIPTION OF THE PROCESS

The organisation under study operates in the manufacturing industry within the milling sector. It uses agricultural produce to manufacture a wide range of modified, unmodified as well as refined products which are supplied to manufacturers of beverages, foodstuffs and a variety of industrial products. It has four processing facilities in the country which supply local and export market.

Demand for products is cyclical comprising periods of low and high demand. These facilities are therefore required to ramp output up or down in response to the market demand. Flexibility to respond to market swings is essential and it allows continuous operations from all four facilities through the business cycle. The facility used in the study is situated in Gauteng. It has the capacity to process 1 200 tons per day of raw material; however, capacity utilisation ranges from 65% to 80% depending on the market demand.

Raw material used by the organisation consists of four components in different proportions. On receipt, quality inspection is carried out to ascertain that material delivered comply with specification. It is stored on site and inventory levels are managed to keep continuous supply for processing. Raw material is prepared before each component is separated and processed further into the final product which is ready for the market.

A three-stage separation process is employed where component 1 is separated first, followed by component 2 with components 3 and 4 separated simultaneously. The first two stages of the process use mechanical separation whilst the third stage employs scientific principles to effect separation. After separation the four streams are processed further to produce the final products using different channels. Performance from each channel is measured by how well each component was recovered from the raw material processed and it is expressed as percentage yield. Although different parameters are measured and monitored to control and influence process performance, percentage yield is the ultimate measure of performance from which profitability is determined. The evaluation conducted below is based on separation and recovery performance.

Processes are evaluated by measuring different aspects to determine the level of effectiveness. The interpretation given is used to highlight the level of process performance on which deductions can be made regarding variation in the process and whether the opportunity exists to improve process efficiency. The four areas that will be used to evaluate process effectiveness are discussed below.

3.3 EVALUATION

3.3.1 Defect rate

Defect rate involves measuring the number of output units with defects, commonly referred to as non complying units. This is a measure to determine the effectiveness of the process by detecting defective units produced highlighting the extent of variation in the process. The higher the number of defective units produced, the less effective is the process. Such processes display high levels of variation hence the increased rate of non compliance. On the contrary, a process which generates low defects is deemed effective and levels of variability are low – an indication of a more acquiescent process. Such a process is not only operating at high levels of effectiveness, it is also performing efficiently as well at optimum levels as dictated by designed capabilities.

- **DPU – defects per unit**

  This measure involves measuring the total number of defects that occur over a known number of units, giving a basic assessment of process effectiveness.

- **DPMO – defects per million opportunities**
  This is a measure of defects generated by the process in every million opportunities. Because most processes are complex, using DPU might ignore some characteristics of the process. A more encompassing measure to take cognisance of process complexity lies in measuring DPMO.

3.3.2 Yield level – performance within specification

Commonly referred to as First Time Yield (FTY), Sigma yield represents the effectiveness of the process by comparing the input to output including rework and waste. Traditional yield represents process effectiveness by comparing input to output including waste only. It ignores reprocessing of material which failed specification and was therefore reworked or reprocessed to correct defects. In contrast, Sigma Yield captures process effectiveness as a once through pass without any correction made to non complying output. Dasgupta (2003:358) explained that Sigma Yield uncovers the hidden factory as expressed in process losses and increased rework. Unlike the conventional yield, it looks at process output in its totality whether it is conforming or non conforming to specification.

Expressed in a formula form:

Traditional Yield (Y):

$$Y = \frac{\text{Input - scrap}}{\text{Input}}$$

First Time Yield (FTY):

$$FTY = \frac{\text{Input – scrap – rework}}{\text{Input}}$$

3.3.3 Sigma level – Z-score

A process Sigma level denotes the degree in which the process fluctuates by measuring the number of standard deviations between the process mean and the specification limit. Levin et al. (2008:111) regard Z-scores to be useful in identifying outliers, which are values located far away from the process mean. The further away a value is from the process mean or specification limit the higher the Z-score and process sigma.

According to Thawani (2004:657), a higher process Sigma level means a process generates fewer defects resulting in consistent output and displays a lower value in DPMO, an indication of low process variation. The highest process Sigma score is stipulated as six hence the term Six Sigma. At this level, the process is operating at near perfect state, from which the highest effective and efficient level is attained. Even at this Sigma level, variation is still present hence processes cannot achieve perfection but it is limited to process design inherent variation whilst any other type of variation is eliminated.

Processes with lower Z-score figures display high levels of defects and variability. Sigma level expresses probability of a process to produce defects. High Sigma level denotes lower probability to generate defects, alluding to a more effective and efficient process. In contrast, a less effective process with high variation has a lower Sigma level or Z-score. Thawani (2004:656) asserts that most companies on average are operating processes at Sigma levels of between two and three, which lead to costs amounting to 10% to 20% of revenue.

The Six Sigma fundamental concept is based on reducing the defect rate along different Sigma levels as observed by Han et al. (2008:22). Defects generated from the process can be reduced by controlling the Sigma level of that particular process. As it has been mentioned earlier, processes scoring on the upper end of the Sigma scale are characterised by low defect rates.

According to Dasgupta (2003:456), a process that operates at Six Sigma level generates defects not exceeding 3.4 defects per million opportunities whilst a three Sigma level process generates 66 809 defects per million opportunities.

3.3.4 Process capability

Stevenson (2005:451) defines process capability “as the inherent variability of process output relative to the variation allowed by design specification”. This defines the ability of the process to consistently produce at levels which meet customer requirements despite variation displayed within the process. However, this is only achievable when the process variability is limited to natural variation or common cause variation attributed to process design factors. Six Sigma methodology seeks to operate processes with natural variation only, leading to a process with high compliance levels enabling a more predictable process outcome.

At high variation levels processes are not consistent and predictable in producing at levels which meet customer requirements. Against this backdrop, process capability can be expressed in terms of variation whereby capability infers to the level or rate of variability present in the process which then diminishes the ability of a process to deliver customer requirements. The higher the variability the less capable is the process and the vulnerability of the process to meet customer expectation or requirement is increased.

Contrary, low variability signifies a more capable process which is prone to deliver within specification, enhancing the capability of the process to meet customer expectation consistently and creating a state where the voice of the process matches or fits the voice of the customer. Processes can move from capable to a state of not capable as a result of increased variation attributed to equipment wear and tear, as an example. Therefore, it is a natural tendency for process performance to decline over time signalling among others the effects of equipment deterioration. Understanding this phenomenon brings forth two prone approaches, the necessity to prevent the increase of variation as well as endeavours to reduce variation as an ongoing mission to manage process capability.

As a general rule in measuring process capability, a process with factors below one is regarded as not capable to perform consistently as expected. Operating at such levels, processes are characterised by inconsistent performance, are less effective and are accompanied by low efficiency levels. Processes achieving factors greater than one are deemed capable, consistently performing as expected which is a measure indicative of the ability to satisfy customer expectations or requirements. Capable processes are characterised by high levels of effectiveness and efficiency as advocated by Six Sigma methodology.

Ideally, processes must be operated within designed conditions in order to attain the optimal performance and best results. At these, process capability is at its highest and variation at its lowest. Design factors dictate the level of process variation and such variation is referred to as natural or common cause variation. Operating processes within designed conditions does not guarantee the presence of common cause variation only; other forms of variations develop with time and the effect of increasing variation on the process needs to be closely monitored. It is imperative to implement a counter measure at this stage to keep variation to the common cause type only.

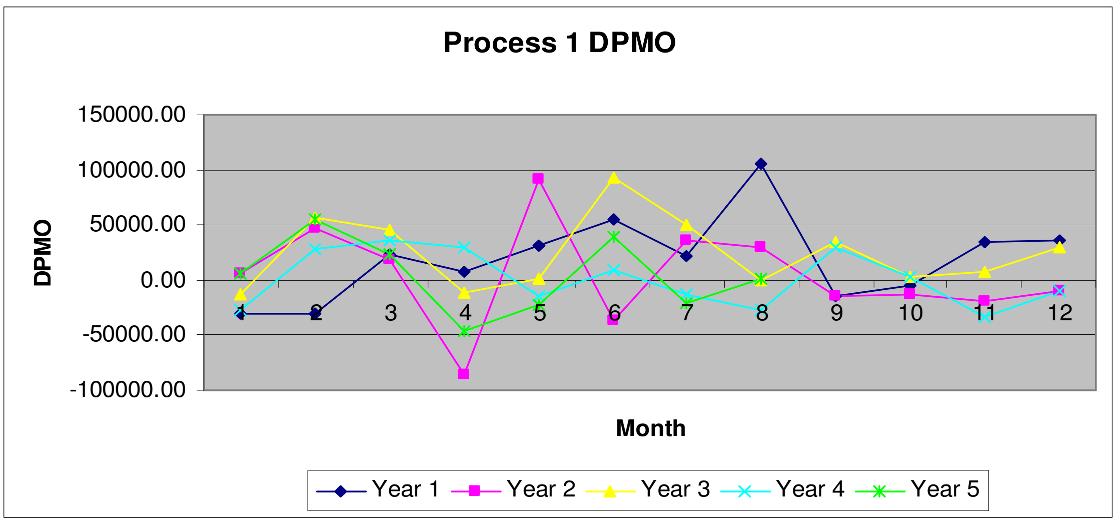
3.4 FINDINGS

The findings are based on the tendencies of processes as displayed by different measured performance aspects over the reviewed period. The purpose is to highlight performance aspects which show desirable tendencies and those with undesirable tendencies. Such an evaluation then provides a more accurate scope of areas which will be prioritised for improvement initiatives. Furthermore, it provides a better understanding of what constitutes good performance or non performance, providing a base for correcting performance and further improvements. Detailed observations, on specific performance aspects, are discussed for each process based on evaluation conducted using Six Sigma tools.

3.4.1 Process 1

- **Defects rate**

Figure 3.1: Graphical presentation of Process 1 DPMO

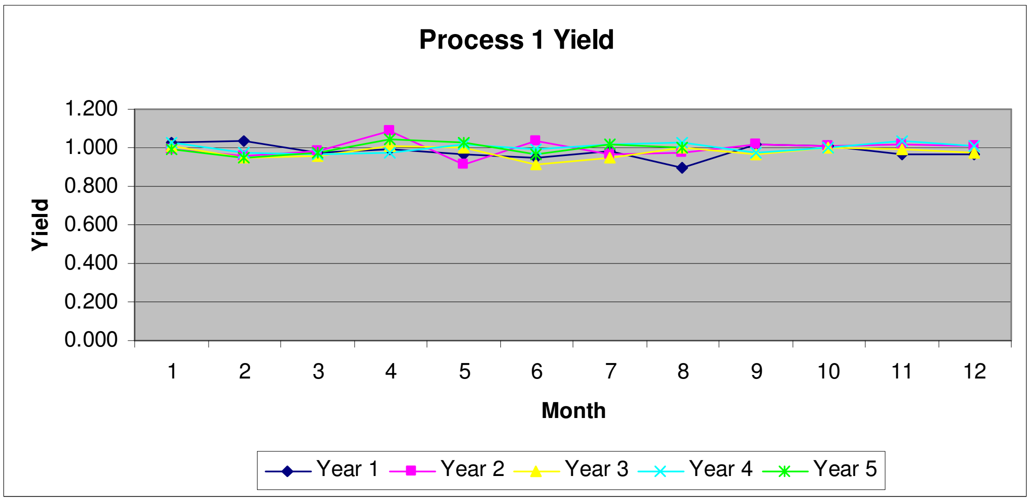


The graph above, in figure 3.1, depicts the number of defects generated by Process 1 as expressed in DPMO. A month-to-month comparison confirms that the process has variation and this phenomenon becomes apparent for the entire review period. To illustrate this point, there are defects in reported results for each month at different varying levels. Glaring is the extent in which variations fluctuates from month to month as depicted by an inconsistent number of defects per million opportunities (DPMO).

Oscillation in DPMO from positive to negative illustrates high levels of variation present in the process, confirming that both types of variations, that are common cause and special cause, are in operation. However, the special cause variation is predominant. This trend is repeated year after year; however, the differentiating factor is in the enormity of the variation. The rate of generating defective units from Process 1 is very high when compared to the Six Sigma standard which advocates for a process not exceeding 3.1 DPMO.

- **Sigma yield**

Figure 3.2: Graphical presentation of Process 1 Sigma yield



Sigma yield depicts the same phenomenon of fluctuation depicted by the defects rate when a month-to-month analysis is performed for the entire review period. This trend is expected as the yield is informed by the number of defects per unit. Generally, fluctuation levels in Sigma yield are not as sharp and pronounced as with DPMO in spite of the defect rate influence on the yield.

Sigma yield trend, in general, as illustrated in Figure 3.2, is characterised by periods of steady fluctuation and the periods where a high degree of fluctuation is experienced are short and limited. In 2006, a declining trend was observed in Component 1 yield whereas the other years, 2007 to 2010, indicate an upward trend which shows sharp and consistent increases in the yield in the last two years.

Year-on-year comparison affirms monthly performance. Similar trends are depicted where defect rates and Sigma yield are illustrating levels of inconsistency in performance.

- **Sigma level**

Process Sigma levels range from 3.35 to 3.69 over this period, regarded as a 3.5 Sigma process expressed in Six Sigma language. These low Sigma levels affirm the high defects rate embedded in the process and the high potential this process has to contribute value to the organisation. At this Sigma level, the process is generating defective output of 14 000 to 22 000 parts per million opportunity. A process which operates at Six Sigma level generates defects not exceeding 3.4 defects per million opportunities.

The enormous difference between the current process Sigma levels and a Six Sigma process underscores enormous potential value to be derived by increasing process Sigma levels towards the Six Sigma process. A positive upward movement on the Sigma score scale towards Six Sigma level contributes positively in the performance of the process and the improvement will be illustrated by a reduction in DPMO generated.

- **Process capability**

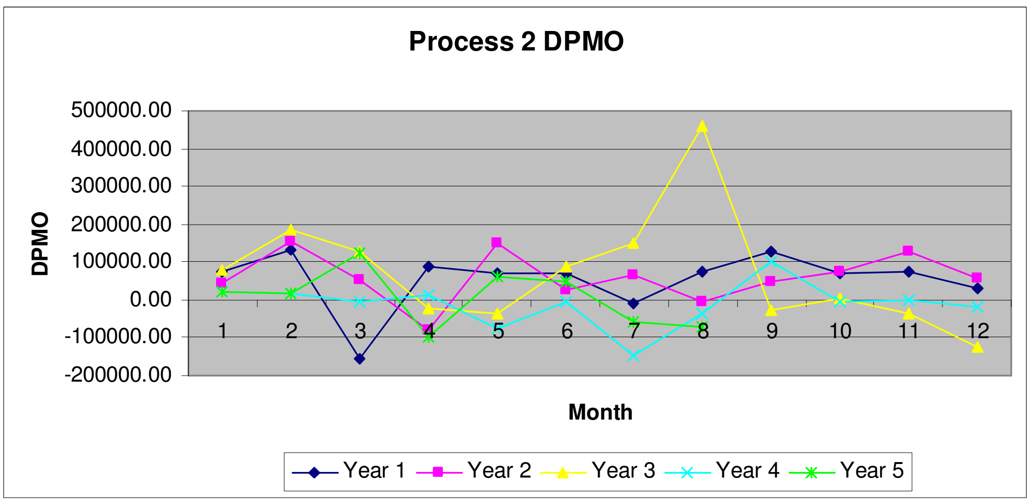
Processes are operating at its best capabilities when process variation is restricted to design inherent variation. Process 1 experienced high variation each year; as a result, the ability of the process to deliver the required output was adversely impacted and manifested into lower process capability factors. Processes which achieve capability factors above one are deemed to be capable and that is a desirable state for a process. Process capability factors below one are undesirable and disabling the process as they result in inconsistent and unpredictable output.

Such processes are unreliable to deliver customer requirements consistently, leading to a mismatch between the voice of the process and the voice of the customer. The tendency of process capability to decline over time are influenced, among others, by equipment lifespan, increased variation and so on, and must prompt the organisation to adopt continuous improvement initiatives to counter the effects of such phenomena. In the absence of such a program, declining process capability is likely notwithstanding accelerated variation.

3.4.2 Process 2

- **Defects rate**

Figure 3.3: Graphical presentation of Process 2 DPMO

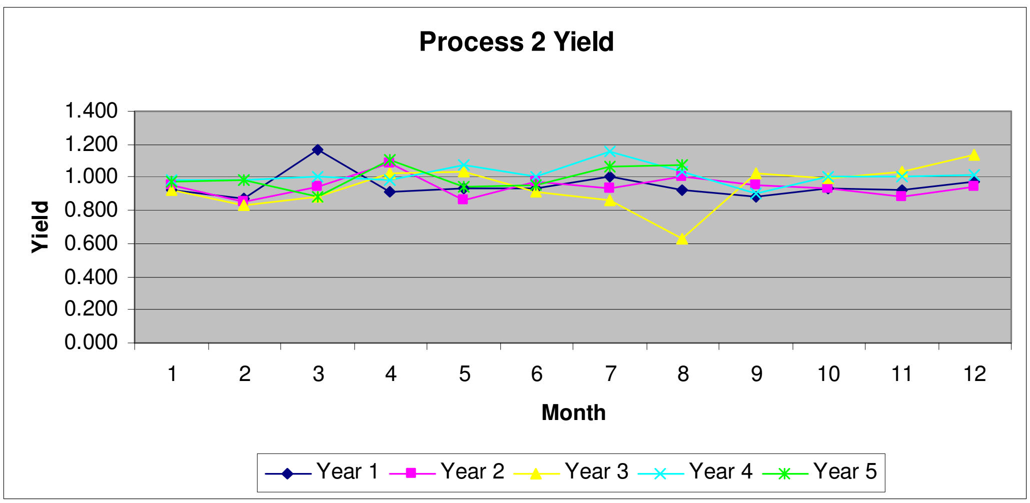


Comparing the Process 2 performance from month to month, as illustrated by Figure 3.3, reveals high levels of defects rate. The magnitude of fluctuations is less pronounced and depicted a much more steady variation in the process throughout the period under review in comparison to Process 1. As expected, DPMO is also high in this process with a shorter range compared to Process 1; however, the trend still confirms that the number of defective units is high for the entire period.

The same trend is repeated year after year; suggesting the same factors causing variations remained operational for the reviewed period. The number of defects as expressed in DPMO indicates the presence and extent of variation and do not insinuate the causes of such variation. An in depth analysis is still required to determine the root causes perpetrating variation in the process. A vast difference exists between Process 2 DPMO and a Six Sigma process DPMO, inferring to enormous potential and value that need to be unleashed from Process 2 by reducing current levels of defects towards the defects rate stipulated in Six Sigma benchmarks.

- **Sigma yield**

Figure 3.4: Graphical presentation of Process 2 Sigma Yield



The calculated Sigma yield for Process 2 follows a similar trend as the defects rate whereby Sigma yield fluctuates month-to-month for each reviewed period. A similar trend is repeated each year, suggesting similar underlying factors to variation are taking place. Although month-to-month yield results reflect variances which give an indication of how much actual result shifted from set standard, corrective measures taken to eliminate variances are not adequate.

Variation is highly visible, suggesting the process performance is influenced by both types of variation. For Process 2, Sigma yield attests to the process generating rework and/or scrap highlighting the need to improve the process effectiveness. Since the organisation uses traditional yield to report monthly performance, the effectiveness of the process is clouded by inclusion of reworked output. Generation of rework could be regarded as part and parcel of normal operation or attributed to upset operating conditions. The notion of averaging yield in reporting process performance conceals the necessity for improving the process effectiveness continuously.

- **Sigma level**

The Sigma level for Process 2 ranges from 2.75 to 3.42 thus Process 2 can be regarded as a three Sigma process operating on the same level as Process 1. Generally, these Sigma levels are regarded low in the Sigma Score continuum. Processes classified as having low Sigma scores display high levels of defects and variability which have been confirmed by the defects rate and Sigma yield discussed earlier.

Whilst the Process 2 Sigma level score is low compared to the Six Sigma performance benchmark, it provides enormous opportunity for improvement and to add value to the organisation. These levels highlight the potential inherent in the process if the current level is increased towards 6, a level advocated by Six Sigma. However, a three Sigma score confirms Process 2 as having high probability to generate defects.

- **Process capability**

The three performance measures, discussed so far for Process 2, depict a high variability process. Process capability also alludes to Process 2 as a high defects generating process when it is put under the Six Sigma microscope.

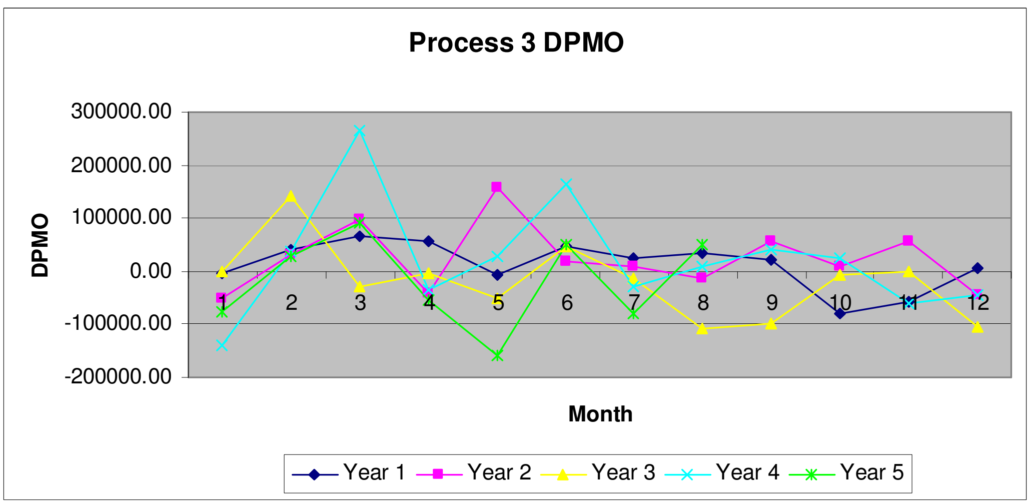
Variation, as discussed earlier, inhibits process effectiveness and therefore it is not surprising for Process 2 to reflect low process capability. A standard rule on process capability is that when a process exhibits figures less than 1, that process is not capable whereas figures higher than 1 affirm processes that are capable.

Process capability figures for Process 2 are below 1 for all the years under review, implying the process is not capable to meet the stipulated specification consistently. Inherent in such process capability level is the difficulty of predicting the performance of the process, rendering the process and the organisation vulnerable to deliver customer requirements consistently. Effectiveness and the potential of the process to perform as designed are highly compromised, necessitating immediate interventions to be taken in order to reverse the impact of variation on process capability.

3.4.3 Process 3

- **Defects rate**

Figure 3.5: Graphical presentation of Process 3 DPMO

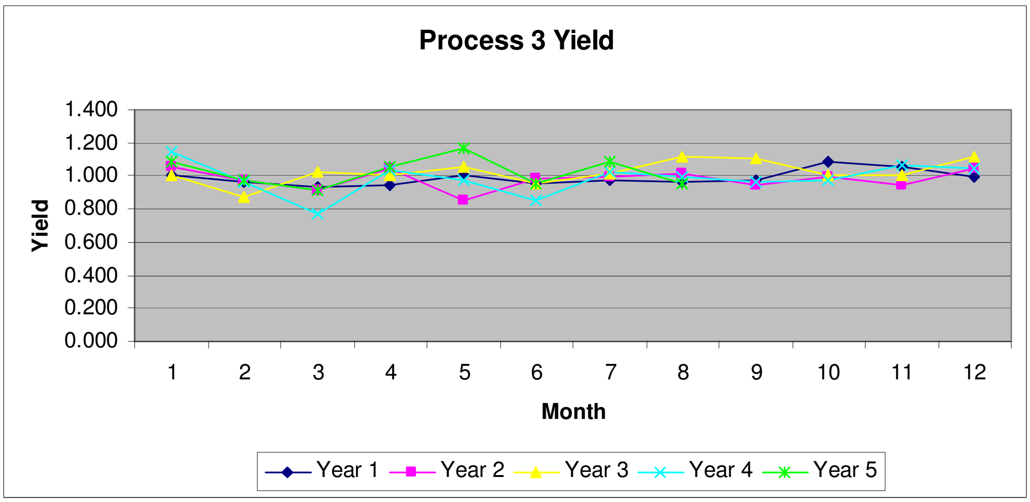


Process 3 also displays high inconsistent levels of defects as depicted by DPMO and DPU figures with varying degree of oscillation from month to month. High levels of defects indicate a process with high variation, which cannot meet requirements consistently. Each year follows a similar trend, implying the same causes of variation remained in operation.

The magnitude of variation is generally high in the first half of each year and it gets smoothed out in the second half of each year. This suggests that the same forces causing a high degree of variation are operational and the corrective measures implemented to counter this effect are effective as far as reducing the degree of variation as opposed to bringing variation under control. The trends show that these forces are not eliminated from the process since they resurfaced each year; however, the measures taken have suppressing effects on them as opposed to eradication.

- **Sigma yield**

Figure 3.6: Graphical presentation of Process 3 Sigma yield



Sigma yield for the process followed a similar trend in terms of oscillating output year on year, indicating the presence of variation in the process. Like all other processes analysed before, Process 3 displayed over and under recovery in the performance pattern. Under or over recovery is directly attributable to the presence of variation in the process. Over recovery does not translate to excellent performance as it can be seen from varying numbers of DPMO and also that performance cannot be repeated even if the process is operated under the same conditions.

Understanding the underlying causes of over and under recovery is paramount and eliminating these causes will reveal the actual Sigma yield of the process, the state which will allow informed decision-making. Considering that the process results reported by the organisation are in the form of traditional yield, the distortions in these results are highly influenced by the rework material produced and reprocessing of such material. The impact of reprocessing is quite apparent when the process over recovering in particular when the rework generated the previous month is reprocessed in the new month.

Under recovery can be attributed to, amongst other factors like losses, poor separation, the generation of rework and failure to reprocess such material immediately in the period in which it was produced. Processes which are subjected to Six Sigma methodology are managed in such a way that rework or scrap produced by the process is eliminated by continually measuring the amount of rework generated, analysing to understand the root cause of rework or scrap and implementing measures that will eliminate root causes and improve the process performance.

- **Sigma level**

Yearly averages of process Sigma level range from 2.88 to 3.36, confirming the Process 3 operational status as a three Sigma process. Processes operating at three Sigma level generate high levels of defects in comparison to the six Sigma process and yet it presents enormous potential and possibilities for improvement. A 2.88 Sigma process displays defects levels as high as 84 000 DPMO whereas a 3.36 Sigma process generates defects at reduced level of about 31 5000 DPMO.

For Process 3 to move from the 2.88 to 3.36 Sigma level, it has achieved an equivalent of 62% in performance improvement. It stands to reason, therefore, that the potential of the process as designed and as built is not fully utilised, an operating condition which Six Sigma methodology intends to rectify. Six Sigma add value to the organisation by unleashing the potential of the process through rectifying such operating condition and improving the process in order to perform at the designed capabilities.

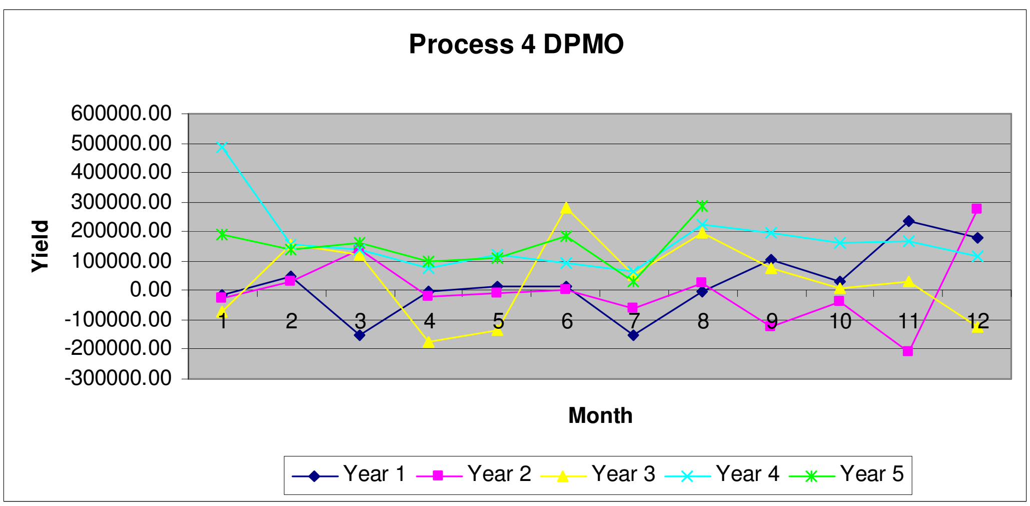
- **Process capability**

Variation is at the core of process performance regardless of performance measures used, process capability included. Even with process capability the degree of process variability impacts effectiveness and efficiency either negatively or positively; the onus is left on how the process is managed. Variation is experienced in Process 3 as discussed above; however, of utmost importance is the verification of this fact by process capability figures from Process 3, revealing that Process 3 is not also capable to deliver consistent output. All capability factors are below 1, asserting that Process 3 is not operating effectively and efficiently as expected to meet customer requirements consistently. Performance of any process, similar to Process 3, operating with factors below 1 cannot be predicted with ease, making the organisation vulnerable in performance and its ability to respond to market demands competitively.

3.4.4 Process 4

- **Defects rate**

Figure 3.7: Graphical presentation of Process 4 DPMO



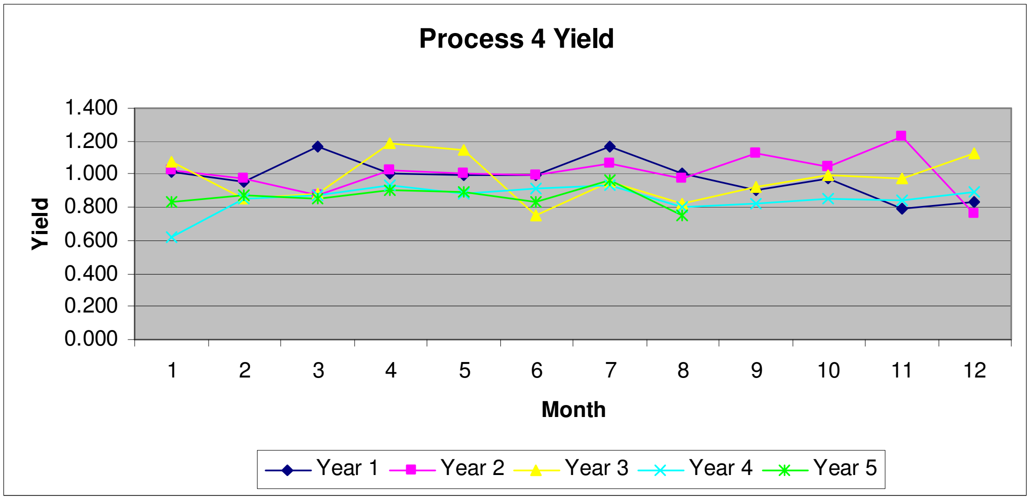
As with other processes, Process 4 follows a trend depicting a high defects rate and quite glaring oscillating levels. High variation does not only suggest the presence of both types of variation but it also alludes to predominance of special cause variation in dictating how Process 4 performs. This is illustrated by increasing levels of defects especially in the last two years.

Increasing levels of defects as indicated by DPMO and DPU have impacted process Sigma levels adversely, depicting a downward trend for the last three years. Defects generated by the process increased from 50 000 DPMO to 136 000 DPMO during the period under review, accompanied by declining process effectiveness and operational efficiency. An increase in the number of defects generated by the process translates to 172% decline in process performance.

The approach employed by Six Sigma in evaluating processes has the unique ability to draw attention to areas that are underperforming and propels immediate actions to be taken by highlighting opportunities lost. Such areas should automatically become a key focus area where energy and resources must be directed. Accelerated variation causing a decline in process effectiveness suggests new additional factors causing variation are at play or the rate of existing contributing factors is also accelerated.

- **Sigma yield**

Figure 3.8: Graphical presentation of Process 4 Sigma yield



Like other performance indicators from Process 4, Sigma yield has seen a downward trend as the defects rate increases. Inconsistency in the effectiveness of the process is more pronounced with Process 4, alluding to Process 4 as a priority area which has the most impact on operational efficiencies. This downward trend suggests immediate intervention is required to arrest the emerging trend. In comparison, the process is rapidly migrating away from as opposed to moving towards Six Sigma benchmarks which should serve as trigger to the organisation to respond with remedial measures.

- **Sigma level**

The process Sigma score determined the position in which a particular process is at on the Sigma score continuum. On Sigma scale the Process 4 Sigma level score is 2.84 on average, which makes it the only process below three Sigma level. A process rated as a two Sigma process has more variability compared to a process operating as a three Sigma process, alluding to Process 4 performing a lot worse than the other three processes.

Variation tends to increase if it is left unattended or if the measures implemented are not effective. Process 4 has the highest potential and more opportunities to bring about notable differences in adding value to the organisation's bottom-line, by improving process effectiveness and operational efficiency. An improvement is envisaged immediately when the Process 4 Sigma score shifts from two towards six, the level of improvement is dependent on the size of the leap taken towards six; however, each positive move taken towards six will add value.

- **Process capability**

The process capability figures from Process 4 are in line with the outcome from the other performance measures discussed above. The Process 4 effectiveness levels are low; as such, it is not capable to deliver within specification consistently. As depicted by the figures below 1, process capability factors suggest current levels at which this process is operated are not desirable. A sharp increase in the number of DPMO generated by Process 4, attest to increased process variations, shifting it further down to lowest levels on the capability continuum. If this downward trend continues and not resolved, fluctuating losses in operational efficiencies will be the order of the day.

In summary, the four processes evaluated experienced variation for the entire period under review. The magnitude of variation varies depending on the process under evaluation. Comparing variation generated in all four processes to the Six Sigma benchmark, the levels of variation are unacceptably high. The impact of high variation is reflected in all process aspects that were evaluated, indicating variation as core to inconsistent process performance. Effectiveness and efficiency of these processes are affected mostly by high variation and possibly by low capacity utilisation in the range of 60% to 80%.

Notwithstanding high levels of variation and the adverse impact on process effectiveness and efficiency, customer supply and satisfaction are partially affected as highlighted by a few incidents of customer non supply and customer complaints recorded for the period. Impeding and inhibiting factors imposed by variation on the process are more pronounced on value creation through process effectiveness and efficiency than on customer supply and satisfaction. Value creation is inherent in how process is operated and this benefit must be derived for the organisation internally as well as externally for the customer. While there is merit for the organisation to create value for the customer, value add is a reciprocated beneficiation between the customer and the organisation. However, in this case the organisation is not gaining much value on operational efficiencies as indicated by the analysis. Persistent fluctuation in operational efficiencies is directly linked to persistent presence of variation in the organisational processes.

Processes perform optimally when they operate under designed conditions including at designed capacity. All four processes are not operated at designed capacity, therefore, they are highly likely to experience other variables that contribute to deterioration of variation and subsequently, process efficiency and effectiveness deteriorate as well.

3.5 CHAPTER SUMMARY

Measures used to evaluate performance of a milling organisation include defective rate, Sigma yield, Sigma level and process capability. On application of these measures to the milling organisation data or results, useful information was generated which can be used to facilitate deductions and decision making about the processes. Each process was evaluated separately however the common metrics used allowed comparison of different processes as well in each aspect of performance measured. All four processes displayed high level of variation when compared to Six Sigma standards.

CHAPTER 4
CONCLUSIONS AND RECOMMENDATIONS

4.1 INTRODUCTION

Chapter four discusses conclusions made from the analysis conducted in the previous chapter as well as listing the recommendations intended to improve performance and operational efficiencies.

4.2 CONCLUSIONS

By utilising some of the basic tools of Six Sigma to conduct a basic analysis to evaluate separation processes performance, significant anomalies were identified in several aspects of the process measured. Although the entire Six Sigma process was not followed, the analysis tools applied provided useful and adequate information from which inferences were made regarding separation processes.

Variation exists in all four processes at varying levels depending on the process and this confirms the notion that every process has inherent variation as explained by literature. The significance of this statement emphasises variation as one of the key factors in the operation of any process and therefore it cannot be ignored during production but its status should be elevated to the same heights accorded to inputs and outputs prior to and during a transformation process.

Systems and procedures entrenched to successfully manage transformation of input to output should be extended to include specific measures intended to influence and predict levels of variation in a process. Such instruments should be directed at exposing variation and creating efforts required to reduce variation on an ongoing basis. Intentionally and actively creating an environment which does not tolerate unnecessary variation but deals with it, not only guarantee efficiency and effectiveness, it also ingrains continuous improvement. The absence of continuous improvement initiatives are directed at incrementally enhancing the organisational performance by focusing on removing process constraints. Such measures if implemented will retard the impact and effects of variation on processes.

Un-monitored variation is a hidden adverse force which paralyses processes to perform at their potential or designed capability and constantly diminishes effective and efficient performance. Processes which experience high levels of variation are disabled and give erratic performance and results. It means the outcome of such a process is dominated by unpredictable efficiencies and quality. Variation does not only impact on the profitability, it also adds more uncertainty to process performance.

Unattended variation becomes a variable that cannot be identified, understood and explained which often lead to inaccurate decision-making particularly when its magnitude is high. In such situations, problem solving and process optimisations are conducted on a trial and error basis, often characterised by an unstructured approach. Against this backdrop, objectives of running efficient and effective processes are nearly impossible to realise.

Monitoring variation in processes presents two options to an organisation. It compels and prompts organisations into action either to eliminate or cope with variation. An organisation employing Six Sigma techniques will certainly implement measures which will eradicate or reduce variation. Elimination of variation is a focal point driving Six Sigma methodology to improve process effectiveness and efficiencies by identifying causes of variation and implementing corrective as well as preventive measures. The parlance is to use data to understand factors generating variation in order to create or design appropriate solutions to mitigate such factors.

The non Six Sigma organisation is likely to manage the impact of variation by implementing measures which will make them cope with the situation. This elaborate approach does not involve proper understanding as to why variation occurs and what are the driving forces behind it. It seeks to give first-aid treatment and bandage the problem as opposed to giving treatment which heals. This approach acknowledges that a problem exists but the process followed to generate solutions to the problem is often haphazard; and therefore incapable of rooting out the source of the problem.

For the Milling organisation under study, variation is not directly monitored but indirectly monitored by comparing actual to a set standard performance as expressed in monthly percentage yield. Because it is indirectly monitored, there are no specific systems and procedures intended in particular to impact variation; therefore, coping mechanisms are often triggered. Any performance around the standard does not always warrant action to be taken because of lack of measures directly intended to address variation. However, where deviations are encountered it is not often a practice to unpack such information so as to understand the causes of deviations.

An averaging approach adopted to report results as expressed in year to date (YTD) does not help the course as it smoothes out deviation or variation and incorrect impressions are creating about the actual performance. Since the organisation experiences such high levels of variations in all four processes, an averaging approach to report results is not ideal and has the potential to exacerbate the problem. Each result needs to be looked at uniquely and addressed as such; relating results by averaging in this case is counter productive.

High levels and magnitude of variation confirm the presence of both types of variation, namely common cause and special cause variations with the latter predominant. This phenomenon is common in all four processes, except that the degree in which variation occurs, differs. Analysis conducted provides a base on which improvement initiatives could be tailored to enhance process effectiveness and efficiency. To build on the foundation which has been laid down, one needs to dig deeper to establish factors driving variation as it manifests itself in the form of both types and fluctuating monthly yield.

Variation as expressed by DPMO or any other measure used provides the organisation with an opportunity to improve or to look at the opportunities which are untapped. Such opportunities reflect intrinsic potential of the process which is the source of value required to enhance operational effectiveness and efficiency. Organisations which are actively monitoring variation by measuring it in any type of metrics enable them to add value in their performance by seizing such opportunities and converting them into value adding activities, benefiting both the customer and organisation, a trait which is a prerequisite for competitiveness.

On the other hand, organisations which do not monitor variation at all in any form are blind to realise the opportunities lost. In essence, there are no indications or warning signs which alert and direct the organisation to potential value adding opportunities. Such organisations could be content with current standards of performance; however, this is a compromised performance when the potential of the organisation dormant is taken into account. Twenty-first century organisations enhance its competitiveness by leveraging and harnessing its internal strengths, potential and opportunities in the process included.

The average Sigma level for all four processes amount to three (3σ), a low rating compared to a Six Sigma process (6σ). Defects generated by separation processes are too high and thus not comparable to Six Sigma levels of defects generation. High defects in a process are a double-edged sword representing two parallel options. High rate serve as a source of concern which slowly erodes away process effectiveness and efficiency if left unattended. Contrary, high defects represent high potential that needs to be exploited to contribute value to the organisation.

Any positive movement from three towards six on the Six Sigma continuum represents enormous improvement prospects to tap the untapped potential of the process which will be reflected through improved operational efficiency and effectiveness. Without any doubt, this organisation has enormous opportunities to exploit and therefore impacts on operational efficiencies by increasing the current process Sigma level towards Six Sigma level. The impact of increasing the process Sigma level will not only be seen through improved operational efficiency and effectiveness but also will be evident in the organisation bottom-line. Any internally engineered improvements leading to savings, whether in cost or operational efficiencies, contribute directly to the bottom-line.

Process capability displayed by the four separation processes show lower capability with all four processes capability factor below 1. This is another way of looking at the opportunities inherent in these processes. During the design of a process, capability is the key factor which is used to ascertain whether the process will be able to deliver as required. Therefore, processes are designed with capability built in them and capable to perform and meet expectations in spite of inherent variation. The lower process capability factors are therefore representing temporary incapability as dictated by currently active capability inhibiting factors. Removing these factors will render the process capable.

Processes are designed and built with capability to deliver and fulfil expectations. However, capability overtime is affected by, among others, ageing of equipment and incorrect operating methods, manifesting themselves in process variation. Separation processes for the milling organisation are capable at least from a process design perspective. Current low levels of capability illustrated by low factors suggest other impediments are at play and inhibit the process to perform at the designed effective levels. Performance impeding factors needs to be identified and eliminated to allow the process to operate as designed.

Processes perform optimally when they are operated at designed conditions where the maximum process capability is unleashed. Running a process at designed capacity will be more optimal and effective compared to running the same process at say 50% of design capacity. Such a move is a disabler. For the milling company to operate at a capacity range of 60% to 80% of designed capacity has already built in it inconsistency in the operation. However, because the flexibility in capacity utilisation is a business imperative, special measures must be taken to understand first the impact of such capacity swing to process capability and efficiency. Afterwards, special measures must be built in and always invoked to counter any performance distortion resulting from ramping production up or down. However, the ideal will be to operate this process at designed capacity.

Although a brief analysis was conducted, it revealed vital pointers towards the root causes of fluctuating operational efficiencies for the milling organisation. A thorough Six Sigma analysis will provide in depth information to facilitate elaborate evaluation which will help to unearth other performance inhibiting factors in the operation.

The study revealed that variation affects different aspects of the process. These aspects are interconnected and need a holistic approach when evaluating process performance. The brief analysis conducted with some of the Six Sigma techniques highlighted that focusing on understanding and reducing variation lead to an increase in both process effectiveness and efficiency by improving predictability and reducing uncertainty in the process. Therefore, Six Sigma has a positive impact on operational efficiencies as long as process variation is continually eliminated or reduced and aiming at operating processes with designed related variation only. When Six Sigma is pursued, it will begin to shift process Sigma level towards Six Sigma status, creating a recipe for predictable operational efficiencies and it is applicable to all processes.

A hidden factory effect is in existence where rework generated from the processes is regarded as part and parcel of operations. Systems and procedures created to manage rework are not only opposing a value maximising mindset but they are also not promoting continuous improvement of operations and processes.

4.3 RECOMMENDATIONS

- Variation should be actively monitored by establishing systems and procedures which gather data and trigger measures to be taken to reduce variation.
- The averaging method of reporting results should be reviewed and the performance of each month should be analysed independently.
- A thorough analysis should be conducted to establish various causes of variation in each process.
- Implementation of corrective measures should be prioritised. The process with the biggest impact should get priority.
- The Six Sigma methodology should be adopted to drive value from operations.
- A full study should be conducted to establish the impact of ramping capacity and mitigating measures should be established and implemented to minimise the impact.
- The impact of reprocessing rework should be determined to reflect the opportunities lost. Alternatives must be provided to minimise reprocessing.

4.4 CHAPTER SUMMARY

Information derived from the analysis was useful and relevant to challenges experienced by the milling organisation regarding fluctuating efficiencies. All four separation processes are characterised by high variation which needs to be actively monitored and eradicated. Contrary to high variation the analysis highlighted huge potential for all processes to add value to the organisation if the performance begins to shift towards Six Sigma benchmark. Based on the analysis, Six Sigma approach can impact operational efficiencies positively by improving process capability.

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