COPYRIGHT AND CITATION CONSIDERATIONS FOR THIS THESIS/DISSERTATION

- Attribution — You must give appropriate credit, provide a link to the license, and indicate if changes were made. You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

- NonCommercial — You may not use the material for commercial purposes.

- ShareAlike — If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original.

How to cite this thesis
The Benefits of Applying the Results Based Management Life-Cycle Approach to the Crushing and Screening Process of Run of Mine

A Dissertation Submitted in Partial Fulfilment of the Degree of

MAGISTER INGENERIAE

in

ENGINEERING MANAGEMENT

at the

FACULTY OF ENGINEERING AND THE BUILT ENVIRONMENT

of the

UNIVERSITY of JOHANNESBURG

by

Khaya Madiba

13 May 2015

SUPERVISOR: Dr Arie Wessels

CO-SUPERVISOR: Professor Jan-Harm Pretorius
# Table of Contents

ABSTRACT .................................................................................................................. 4
GLOSSARY ................................................................................................................... 6
ACRONYMS .................................................................................................................. 8
LIST OF TABLES ......................................................................................................... 9
LIST OF FIGURES ...................................................................................................... 10
ACKNOWLEDGEMENTS ............................................................................................ 11
DECLARATION ........................................................................................................... 12
DEDICATION .............................................................................................................. 13
INTRODUCTION ........................................................................................................ 14
LITERATURE STUDY .................................................................................................. 16
  THE PROJECT MANAGER ......................................................................................... 16
  PROJECT QUALITY MANAGEMENT ......................................................................... 17
  WHAT IS RESULTS BASED MANAGEMENT? .......................................................... 18
    Planning .................................................................................................................. 20
    Monitoring ............................................................................................................ 20
    Evaluation ............................................................................................................. 20
  RESEARCH METHODOLOGY ................................................................................... 20
RESEARCH .................................................................................................................. 24
  DAILY TARGETS ...................................................................................................... 27
RESEARCH FINDINGS ................................................................................................ 31
  METSO LOKOTRACK LT1213 (CRUSHER) .............................................................. 37
  METSO LOKOTRACK ST358 (SCREEN) .................................................................. 40
  CAT 950 H FRONT END LOADER (FEL950) ........................................................... 41
  CAT 966 H FRONT END LOADER (FEL966) ............................................................ 42
  IMPACT STUDY ...................................................................................................... 45
CONCLUSION .............................................................................................................. 52
REFERENCES .............................................................................................................. 54
APPENDICES .............................................................................................................. 56
  APPENDIX 1: RMC MACHINE INFORMATION ...................................................... 56
  APPENDIX 2.1 – OCTOBER 2013 FUEL CONSUMPTION SUMMARY ...................... 57
  APPENDIX 2.2 – NOVEMBER 2013 FUEL CONSUMPTION SUMMARY .................... 58
  APPENDIX 2.3 – DECEMBER 2013 FUEL CONSUMPTION SUMMARY ..................... 59
  APPENDIX 2.4 – JANUARY 2014 FUEL CONSUMPTION SUMMARY ....................... 60
  APPENDIX 2.5 – FEBRUARY 2014 FUEL CONSUMPTION SUMMARY ...................... 61
  APPENDIX 2.6 – MARCH 2014 FUEL CONSUMPTION SUMMARY ......................... 62
Abstract

A project is a temporary undertaking by a single person, organisation or multiple organisations to create or run a unique service or result [1]. Mining is a process or business of digging up metals or minerals. When these minerals have been mined, they get processed according to customer/client specification.

This process involves having the mined material, commonly known as Run Of Mine (ROM), hauled by trucks to a designated stockpile area from the mining pit. ROM is stockpiled in such a way that the machines used to crush and screen it, have an easy access to it.

In any project, the end goal is to make a profit while delivering a quality product or service in the best time possible. The use of a Quality Management System (QMS) is implemented by an organisation in efforts to satisfy the needs at which the project was undertaken [1]. A QMS implements policies and procedures with continuous improvements conducted throughout the project timeline as required or appropriate [1].

This case study leads off with a literature study into quality control and project quality management. The substance of the literature study is to understand the expected requirements and characteristics when a project has been undertaken.

The author aims to add value to the discussion of quality control and project quality management, which are characteristics that form part of a QMS and how effective they are by focussing on the Results-Based Management (RBM) Life-Cycle approach. RBM is a life-cycle approach, which is implemented by well-recognised world organisations such as The United Nations Educational Scientific Cultural Organisation (UNESCO), The Organisation for Economic Co-operation and Development (OECD),
United Nations Development Group (UNDG), etc. [2] [3] [4] [5] [6]. It encompasses the use of three fundamental stages during the project life cycle:

1. Planning,
2. Monitoring, and
3. Evaluation.

This minor dissertation focuses on the appropriate alteration in the daily process, after monitoring the process’s shortcomings and evaluating possible solutions, to reduce running costs by reducing the fuel consumption. The result of the evaluation, as analysed by the author, was to reduce the stockpile distances the front-end loaders have to travel during loading and stockpiling. The effects were monitored and evaluated on a month-to-month basis.

Through an analysis of the recorded data, before the implementation of the RBM Life-Cycle approach, there is an increase in the fuel consumption of the CAT 950 H Front End Loader of forty four percent (44%) and an increase of twenty eight percent (28%) for the CAT 966 H Front End Loader.

Once the RBM Life-Cycle approach was implemented from the third month, the results are a clear indication of the direct impact of a project quality management system on the fuel consumption. The fuel consumption decreased over the succeeding five months by forty one percent (41%) and twenty percent (20%) for the CAT 950 H Front End Loader and CAT 966 H Front End Loader respectively.

In conclusion and after the analysis of the research findings, it is analytically true that poor quality control and project quality management could have a negative impact of up to forty one percent (41%). Running a project without quality control measures or a sound project quality management system increases the chances of project failure and/or wasteful expenditure.
**Glossary**

- **Crushing and screening** – a mechanical process of crushing and screening Run Of Mine (ROM) to a specific grading as specified by the client
- **Crusher** – Metso Lokotrack LT1213
- **Screen** – Metso Lokotrack ST358
- **Screens** – 40 mm diamond mesh used as a sieve
- **Feeding** – a process of loading ROM into the crusher by means of using the FEL950
- **Ramp** – a temporary slope constructed before the production to allow the FEL950 to be able to reach the feeder bin of the crusher
- **Production sheet** – a hard copy sheet used on site by operators to record diesel usage, production rate of the machines per hour and any delays that might have been experienced
- **Diesel bowser** – a truck with a nine hundred litre (900 litre) diesel tank used on site to fill up machines that could not be driven to the diesel tank located at the site offices yard
- **Pulley** – a round roller operated by a motor that gives movement to the product belt of the crusher
- **Throat** – a chute-like section of the crusher that follows the feed opening and is directly before the impactor chamber
- **Impactor chamber** – houses the hammers that crush the material to reduce to a smaller size
- **Breaker plates** – a set of thick steel plates installed on the inner part of the impactor chamber where the hammers would grind the ROM against the plates to reduce the material size to the gap setting
- **Gap setting** – the space between the hammers and the breaker plates inside the valve chamber. This setting is set on site according to the required size of material required as a finished product. In this case study, the gap setting was sixty millimetres (60 mm) [7]
• Grizzlies – a set of bars attached to the vibrating system, which filter fine material directly to the product belt. This would prevent excess material from packing into the crusher
Acronyms

- RBM Life-Cycle – Results Based Management Life-Cycle
- ROM – Run of Mine
- RMC – Rash Mining Contractors
- QC – Quality Control
- QCRS – Quality Control and Recording System
- OECD – The Organisation for Economic Co-operation and Development
- FEL950 – CAT 950 H Front End Loader
- FEL966 – CAT 966 H Front End Loader
- PMBoK – A guide to the Project Management Body of Knowledge
- CQMP – Coal Quality Management Procedure as set by Eskom
- QMS – Quality Management System
- UNESCO – United Nations Educational Scientific Cultural Organisation
- UNDG – United Nations Development Group
- BOQ – Bill of Quantities
- USA – The United States of America
List of tables

- Table 1: Coal Quality Management Procedure (CQMP) as per client specification
- Table 2: List of daily targets
List of Figures

- Figure 1 – Crushing and Screening Process Flow Chart
- Figure 2 – The RBM Life Cycle Approach
- Figure 3 – Monthly BOQ Format (Diesel Consumption Analysis)
- Figure 4 – Daily Shift Report
- Figure 5 – Crusher Deck and FEL950 Ramp
- Figure 6 – Finished Product, Under the Screen's Belt Stockpile
- Figure 7 – Fuel Consumption/Hour – October 2013
- Figure 8 – Fuel Consumption/Hour – April 2014
Acknowledgements

I would like to thank:

- Special thank you to Mr Mulalo Colin Tshivhase for the opportunity of being exposed to the environment where I got the idea to do my research topic.
- Dr Arie Wessels for the assistance and guidance in the preparation and the drafting structure of my dissertation.
- I believe this study will encourage my partner, siblings and friends to keep on studying, and never stop learning. Things can be taken away from oneself, including life itself, but one’s qualification and knowledge can never be taken away.
Declaration

I hereby declare that all the research work, data collection and analysis, except wherever it has been appropriately acknowledged by relevant references, is my own work.
Dedication

• To my mother Nandi Siwahla-Madiba who strove to ensure that I have everything I need, including being my pillar of motivation. Thank you for the prayers and support.

• To my brother Luyanda, thank you for the sacrifices that you made for me to be able to be at this point in my life.

• To my fiancé Lerato, thank you for the constant reminder to stay true to my goal, the prayers, motivation and support you gave me mentally and emotionally.
**Introduction**

Mining is a process or business of digging up metals or minerals. When these minerals have been mined, they get processed according to customer/client specification. The *Crushing and Screening* process is one that carries out the processing of the mined material. This process involves using a set of machinery, which are capable of crushing and screening the mined material to a specified customer/client specification.

The crushing and screening process involves a number of machinery used to crush and screen to a finished product to achieve customer/client specification in a cost effective, high quality and well time-managed manner.

This process involves having the mined material, commonly known as Run Of Mine (ROM), hauled by trucks to a designated stockpile area from the mining pit. The ROM is stockpiled in such a way that the machines used to crush it, have an easy access to it.

Machines used in this case study, also listed in Appendix 1, are as follows:

1. CAT 950H Front End Loader - used to feed the machines with ROM [8],
2. Metso LT1213 Impactor – used to crush ROM,
3. Metso ST358 Screen – used to screen crushed ROM through sieves, and
4. CAT 966H Front End Loader – used to stockpile the finished product [9].

The quantity of the crushed material is dependant on the hourly rate that the machines are designed to produce and how much they actually produce while in operation. There are factors that affect the optimum performance of the machines. Some of these factors are labour performance, time management, resource planning and allocation, maintenance scheduling, etc.
This study is based on the mining company, which will be referred to as Rash Mining Contractors (RMC) for the sake of confidentiality. RMC was contracted to produce a specific size particle grading of crushed coal, which was to be transported to the client’s stockpile area.

Subcontractors who have been contracted by the client to haul the material to the client’s stockpile area carry out the transportation of the finished product. The material is transported on side-tipper trucks. These are trucks that have two trailers, when full were restricted to carry no more than thirty-three tons (33 tons) from site to the client [10].

This minor dissertation aims to provide a view and assessment of the fuel consumption effects of a Results-Based Management (RBM) Life-Cycle approach in the crushing and screening process on a coalmine. RBM, in summary, is executed in 3 steps: planning, monitoring and evaluation.
Literature Study

The Project Manager

The project manager is a person assigned by the organization to achieve the project objectives [1]. Project objectives are goals/milestones set by the organization during the inception phase of the project [1]. Objectives are set in efforts to achieve the goals/milestones and assist the project manager in having a clear end-goal when carrying out his/her duties and responsibilities.

Depending on the organizational structure of the organization, the project manager may report to the directors or the chief operations officer of the organization [1]. There are many tools and techniques that are recognized as good practice in the project management field, but these alone are not enough for effective project management [1].

The Guide to the Project Management Body of Knowledge (PMBOK) describes three other characteristics that a project manager, whose goal is to be deliver effective project management, should have [1]:

1. Knowledge. This is specific to what the project manager comprehends about project management [1],
2. Performance. Refers to what the project manager is capable of accomplishing while applying his/her project management knowledge [1], and
3. Personal. This characteristic refers to the project manager’s behavioural actions when performing activities related to the project. Personal effectiveness embodies attitudes, personal characteristics and leadership skills, which is fundamentally having the ability to guide the project team
while achieving the set project objectives and harmonising the project controls [1].

The project management standards are increasingly being regarded as an essential attribute in modern organisations [11]. A project manager that lacks the necessary skills and experience is a concern that could jeopardise the success of a project [11].

A project manager needs to have attributes of a leader. There are various types of leaders, whether in a medical industry as a doctor, a teacher in a school, or even a financial manager, which have their own various types of leadership styles [12]. It is essential to have the type of management style that will be in line with the organisation’s vision or/and the project objectives.

It has been found by Galvin and team that a project manager can be effective and efficient by applying analytical thinking, being able to adapt to new projects that come with a change in environment and leadership characteristics [12].

**Project Quality Management**

Geoff Reiss once stated that project management is like juggling three balls; time, cost and quality. Program management is like a troupe of circus performers standing in a circle, each juggling three balls and swapping balls from time to time [13].

Project quality management refers to the processes and activities that are implemented on the project to satisfy the needs of the project objectives [1]. Project quality management is achieved by the successful implementation of a quality management system, through its policies and procedures with continuous process improvement undertakings throughout the project, as appropriate [1].
PMBok provides an overview of the quality management process, which includes the following [1]:

1. Plan Quality - This is the process that is executed before the start of a project. The process involves ascertaining quality requirements as required by the client/customer and documenting the process flow that will be necessary to meet those project quality requirements,
2. Perform Quality Assurance - This process involves the auditing of the quality requirements and the execution thereof, and
3. Perform Quality Control – The process of monitoring, assessing performance and recommending solutions that may be used to improve on the quality requirements.

What is Results Based Management?

A solid RBM system is a life-cycle where results are the most important aspect of planning, monitoring and evaluation, reporting and on-going decision-making [2]. The life-cycle involves the use of the evaluated results to assist in the decision-making during the planning stages of a project. The life-cycle approach can be implemented across different types and scopes of projects, from manufacturing products to general project management.

It includes implementing the different stages of the approach at a management level. The key aspects include the involvement of stakeholders throughout the management life-cycle in defining of expected results, assessing all the possible risks, monitoring the progress during the process, reporting of the progress and results, and using these in management decisions [14].

The Organisation for Economic Co-operation and Development (OECD) was formed with the mission to promote policies that will improve the economic and social well
being of people they assist around the world [6]. OECD is formulated by countries, which are registered in the organisation. They provide a forum for the registered countries to work together by sharing experiences, common problems and seek solutions to those common problems [6].

In the 1990s, the OECD member countries were faced with similar problems such as economic ones due to budget deficits, political and social problems, growing demands for better and more responsive services, and better accountability for achieving results with taxpayers’ money [15]. In 1993, United States of America introduced the RBM life-cycle approach within the administration of President Bill Clinton and they continue to utilise the approach [15].

In 1998, Mark Malloch Brown was appointed administrator and was to use the RBM life-cycle approach as a management tool, which was when the UNDP-RBM was also introduced [15]. Canada was introduced to RBM by the office of the auditor general within the federal government [15].

RBM is defined as a broad management strategy and is aimed at achieving positive changes by improving performance [15]. Three main phases of the RBM life-cycle approach can further be broken down into seven elements. These elements include:

I. Identifying clear and measurable objectives or expected results.
II. Selecting indicators that will be used to measure the progressive progress.
III. Setting targets for each indicator.
IV. Developing performance-monitoring systems to collect all the relevant data.
V. Reviewing, analysing and reporting the actual results.
VI. Consolidating all the performance information from the data.
VII. Using the performance information with internal management.
**Planning**

The planning process of the RBM life-cycle approach is the first step in the process. This involves the stakeholders and management communication. Once the objectives and goals of the project’s success have been identified, the effort to carry out a step-by-step implementation plan is drafted.

**Monitoring**

The monitoring process is spread over the operations. This is the process of using tools to track the progress of the project and identify areas that require adjustment [1].

**Evaluation**

This is a process of analysing the recorded data during the monitoring phase to identify possible solutions that can improve the processes and can be used during the next planning phase [1].

**Research Methodology**

The motivation for carrying out this study was due to the author thinking that he could save the company costs through reducing the fuel consumption of the machines, if RMC used the RBM life-cycle approach on the project management of the crushing and screening process of ROM.

This case study includes a brief literature study on the topic of RBM and how it forms part of the topic, quality control and project quality management. The study will contain an initial assessment of the *Quality Control and Recording System (QCRS)*
and its fuel consumption effects to the project over a total period of seven months. The total assessment was carried out over a period of seven months, with monthly variations introduced by the author to the daily operations from the monthly assessments. This was carried out in the efforts to test the results-based management life-cycle approach on the crushing and screening process of ROM on a month-to-month basis.

It will then continue to provide the methodology used by the author to identify these negative effects and how their mitigation affected the project’s machine fuel consumption. The effects are provided by the author in the form of monthly analysis of the magnitude of the effects, whether good or bad.

The RBM approach is a life-cycle approach in the managing of projects/processes. The approach/methodology that the author implemented involved implementing the recommendations made in the monthly reports, after evaluating where best to try and reduce the running costs. Figure 1: RBM Life-Cycle, is a diagram that indicates the step-by-step cycle that the approach is summarised into.

The research also comprised of evaluating the results of the implemented recommendations and the selected ones being:

1. Increasing the ROM stockpile size/height.

2. ROM that would be stockpiled near the crusher and screen which remained stationary at one point of operation.

3. Reducing the traveling speeds of the loaders.

4. Creating two ROM stockpile areas on the boundary of the stockpile area.
The United Nations Educational, Scientific and Cultural Organisation (UNESCO) was created in 1945, after the occurrence of two world wars in less than a generation [4]. UNESCO strives to build networks between nations to establish peace on the basis of humanity’s moral and intellectual solidarity [4]. The organization believes that education is a fundamental human right and it is also a prerequisite for human development, they also believe in intercultural understanding, pursuing scientific cooperation and protecting freedom of expression [4].

UNESCO has embarked on a reform process of the organization [3]. They used the RBM life-cycle approach within the Bureau of Strategic Planning Division in their
efforts to reinforce their staff’s capabilities [3]. Just like any other process, RBM life-cycle approach is only effective when people implementing it understand the core principles, which is why UNESCO embarked on a mission with the objective of training their staff over a period of time [3].

In this case study, the author will shed an overview, specific to the crushing and screening process of ROM, by highlighting:

- What are the negative effects of a poor quality control and project quality management system?
- How can the RBM life-cycle approach affect the crushing and screening process of ROM?

I expect this case study to contribute to the reader that having a quality control and a quality management system will optimize production, optimize resource utilization, reduce fruitless expenditure and minimize running costs, and by using RBM life-cycle approach, operations can be consistently improved over time. It will also conclude with suggestions, which will best advise how RMC should maintain the variations introduced by the author in the efforts of achieving optimum fuel consumption of the process and consistently improve or maintain optimum profits.

The crushing and screening process is a process that is carried out with the main objective being the achievement of the minimum requirements as per the client’s specification. The process is continuous and allows small room for error of the finished product. The RBM life-cycle approach within the crushing and screening process is specific to continuously improving the process.
Research

In an interview, Robert Kiyosaki said that it is not how much you make that counts but how much money you keep. A registered private company’s goal is to make profit thus making the whole project centred on profitability.

The crushing and screening project’s site establishment was conducted in September 2013. The author was the first one on site as the Assistant Manager and Site Supervisor. Production testing started within September 2013 where the recorded data, which was regarded as relevant by the directors, was the fuel used per month, the amount of processed ROM in tons and the hours of the machines.

The wear and tear of the four machines used in the two-stage crushing and screening process was not according to the recorded kilometres they travelled, but rather the number of hours they were in operation. This is due to the fact that the Metso Lokotrack LT1213 (Crusher) and Metso Lokotrack ST358 (Screen) have to be stationary while in production, as manufactured by Metso International. The CAT 950 H Front End Loader (FEL950) and the CAT 966 H Front End Loader (FEL966) on the other hand moved around to ensure that the process flow was continuous, but they were also not recorded in kilometres, but in hours.

The four machines wear and tear recording was according to the hours that the machines were in use [8] [9] [16] [17]. The hours were recorded by the machines’ operating system and were recorded on site at the start of each shift during the pre-start checks that were conducted daily according to the Health and Safety Act of 1996 and the maintenance manual of each of the machines [8] [9] [16] [17] [18].

There were running costs that had to be satisfied, from salaries for the employees to the fuel used for the process. Minimising these costs was vital to maximise profits. The project quality management system, which was put in place in October 2013,
was able to record the data that was used in this case study. Due to the size of the data captured, which was over one hundred and forty three working days (143 days), the summary of the data is attached from Appendixes 2.1 – 2.7 for ease of reference.

Factors that affected the fuel consumption of the whole operation were recorded and analysed by the author over a seven-month period. The most contributing factor was the diesel usage, which covered thirty percent (30%) to fifty percent (50%) of the total costs for running the project. Consideration of the factors, which directly affected the total financial spending on the project on a month-to-month basis, consisted of influences that were considered for the running of the whole project.

The influences considered on this case study are listed in Figure 3, with fuel being the most expense; labour, wages (cost to company), accommodation, transportation, health and safety, machines, offices, stationary (including printers and laptops), spare parts, fuel to run the machines and maintenance. The author, on the expense that is fuel, carried out the main focus for the basis of the RBM life-cycle approach. To achieve this, the daily targets had to be in place and understood by the full team.
Figure 3: Monthly BOQ Format (Diesel Consumption Analysis)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
<th>DIESEL</th>
<th>UNIT</th>
<th>CONTRACT UNIT RATE</th>
<th>PLANNED QUANTITIES</th>
<th>QUANTITY THIS CERTIFICATE</th>
<th>AMOUNT THIS CERTIFICATE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CRUSHING AND SCREENING</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>ROM - Crushing and Screening</td>
<td>Wet</td>
<td>Tons</td>
<td>21.00</td>
<td>100000.00</td>
<td>21,449.06</td>
<td>R 450,430.26</td>
</tr>
<tr>
<td>1.2</td>
<td>SUB TOTAL: CRUSHING AND SCREENING</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R 450,430.26</td>
</tr>
<tr>
<td>2</td>
<td>SITE INSTRUCTIONS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>Diesel</td>
<td>Liters</td>
<td>R 12.65</td>
<td>16,065.00</td>
<td>R</td>
<td>-203,222.25</td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>SUB TOTAL: SITE INSTRUCTIONS</td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>R</td>
<td>-203,222.25</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R 247,208.01</td>
<td></td>
</tr>
</tbody>
</table>

Source: Madiba 2013

Figure 3: Monthly BOQ Format (Diesel Consumption Analysis) is an illustration of the format used on site to record the monthly fuel costs. The total fuel quantity used by the crushing and screening process over a month comprised of the fuel consumed by the four machines used during the process. This illustration of October 2013 displays that the fuel expense made up forty five percent (45%) of the costs earned, from the crushing and screening of ROM. The practical exercise was started on the notion that reducing the diesel consumption on the machines would reduce the total monthly usage and thus a reduction in the total fuel expenses.

After a successful site establishment and commencement of production of the crushing and screening process in October 2013, the author found that the lack of quality control and a project quality management system did not allow the project to perform at its best. The project quality management system in place was only to record the data. It lacked the management part to analyse the recorded data so that the process could be continuously improved [1].
The engines of the machines on the mine ran on diesel fuel, which was procured from a mass distributor at a cost of twelve rand and sixty-five cents (R12.65) per litre. The aim of this case study is to measure the fuel consumption consequences of having a poor quality control and project quality management system. Through the utilisation of a simple system, the RBM life-cycle approach, which is a form of quality control and assurance and how this affected the crushing and screening process of ROM.

In a journal published in 2012, Christopher R. Knittel writes about his findings when researching *Reducing Petroleum Consumption from Transportation* in the United States of America (USA). USA consumes more petroleum-based liquids per capita than any other of the countries in the OECD [19]. It consumes thirty percent (30%) more than the second-highest country (Canada) and forty percent (40%) more than the third highest (Luxembourg) [19].

In the journal, Knittel states suggestions that would contribute to reducing of the fuel consumption. These being through high fuel taxes, improved fuel economy of the engines, alternative fuels, replacing the internal combustion engine and the forgotten channel: reductions in vehicle-miles travelled [19]. This case study is based on the most simple and effective way to reduce fuel consumption, which directly reduced the running costs of the crushing and screening process.

Project quality control ensures that recorded data is analysed and dependant on the results, changes can be made to best improve the process [1].

**Daily Targets**

RMC had spread out its employees in the efforts of running a twenty-hour operation per day, split between two shifts of ten hours each. Project time management, project quality management and project cost management targets were set based
on achieving the minimum target set by the client. The internal target that was set by the author was meant to motivate the employees to work toward achieving that target. The internal target was to achieve a daily production target of four thousand eight hundred tons (4800 tons) a day, an extra two thousand eight hundred tons (2800 tons) more than the expected daily tonnage by the client.

In any operation, time for maintenance must be allocated within the planning stages. The expected machine availability was estimated at eighty percent (80%) by the directors. Over the seven-month period, the recorded and calculated availability was eighty six percent (86%) [20].

<table>
<thead>
<tr>
<th>Product rate (Tons per hour)</th>
<th>Consignment (tons/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>2000</td>
</tr>
<tr>
<td>200</td>
<td>4000</td>
</tr>
</tbody>
</table>

*Source: Eskom 2013*

The author believes in the three core elements that make a project successful. These elements can only be effectively considered once the project risks have been considered during the planning/project inception phase. They consist of project time management, project quality management and project cost management [1]. Elements that influence the achievement of these targets, specific to this case study are listed in Table 2.

Cost-effectiveness and efficiency are influential elements of a successful project, success being expressed as the profitability of a project and client satisfaction. By lowering the running costs of a project, the major benefit becomes higher profits. Cost-effectiveness analysis of an intervention is the assessment of whether the same, or greater, results can be achieved at a lower running cost through alternative
intervention approaches [5]. The purpose is to use informed measures and record them to ensure the most cost-effective plan is implemented, which can also be improved in the future [5].

Efficiency is the measure of how economical inputs are transformed into results [5]. The author prioritised three elements that he believes to be a catalyst in the success or failure of achieving optimum profits within the project. The research is based on close monitoring of the affects of introducing a variation in the efforts to minimise the running costs, mainly the diesel fuel consumption of the machines.
Table 2: List of Daily Targets

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sign in</td>
<td>hour</td>
<td>0.25</td>
</tr>
<tr>
<td>Toolbox talk</td>
<td>hour</td>
<td>0.25</td>
</tr>
<tr>
<td>Pre-start checks</td>
<td>hour</td>
<td>0.25</td>
</tr>
<tr>
<td>Machine warmup</td>
<td>hour</td>
<td>0.25</td>
</tr>
<tr>
<td>Production</td>
<td>hour</td>
<td>8.00</td>
</tr>
<tr>
<td>Machine cooldown &amp; general inspection</td>
<td>hour</td>
<td>0.25</td>
</tr>
<tr>
<td>Machine cleaning &amp; general inspection</td>
<td>hour</td>
<td>0.50</td>
</tr>
<tr>
<td>Sign out</td>
<td>hour</td>
<td>0.25</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>hour</strong></td>
<td><strong>10</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>As per process design</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tons per hour</td>
<td>tons</td>
<td>300</td>
<td>350</td>
</tr>
<tr>
<td>Total tons per day</td>
<td>tons</td>
<td>2400</td>
<td>2800</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description Per Machine</th>
<th>Unit</th>
<th>As per process design (based on past company projects)</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAT 950H Front End Loader</td>
<td>L/hour</td>
<td>19.827</td>
<td>19.38</td>
</tr>
<tr>
<td>Metso LT1213 Impactor</td>
<td>L/hour</td>
<td>34.559</td>
<td>34.26</td>
</tr>
<tr>
<td>Metso ST358 Screen</td>
<td>L/hour</td>
<td>17.727</td>
<td>16.16</td>
</tr>
<tr>
<td>CAT 966H Front End Loader</td>
<td>L/hour</td>
<td>24.66</td>
<td>24.17</td>
</tr>
</tbody>
</table>

*Source: Madiba 2013*
Research Findings

This research topic is based on actual recorded data to evaluate performance. Recorded data reflects the total tonnage of coal, over a ten-hour shift, number of litres filled on the machines and the total number of staff that had reported for duty.

The data analysis performed by the author was carried out on the amount of hours the machines had been in operation and the fuel used by the machines during the shift. The factors affecting the fuel consumption had to be addressed in the efforts of changing/amending/limiting those factors to try and reduce the fuel consumption, which was the highest cost of running the project.

The author continued to start with the evaluation of the process as a whole, from the machine operations, traveling distances and speeds, material size and material density.

Appendix 3 illustrates the layout of the mining area. The total mining area consisted of the mining pit including the box cut areas, the site offices with an emergency assembly point, workshop area and a stockpile area. The stockpile area made up one hundred and seventy five thousand square meters (175000 m²) of land. As indicated in Figure 4, the client requirements were strict at having no less than four thousand tons (4000 tons) at two hundred tons (200 tons) per hour rate. The stockpiles had to be built up to two thousand tons (2000 tons) per stockpile.

Two of the four machines used in the crushing and screening process are machines that must be static while in operation [16] [17]. These machines form the core component of the whole process by crushing and screening the material. The Metso Lokotrack LT1213 (Crusher) and the Metso Lokotrack ST358 (Screen) are machines used to essentially crush and screen ROM.
Metso, a well-established mechanical French company, manufactures the machines separately and the combination of the machines used is dependant on the ROM and finished product requirements. In this case study, the combination was designed on a two-stage crushing and screening combination. The term stage refers to the amount of different stages ROM material passes through to be stockpiled as a finished product, excluding loading and stockpiling carried out by the front-end loaders.

The machine availability per month was a contributing factor in the research. The author believes that the larger the data set, the more accurate the result. The availability of the machines meant that production was in progress.

Recording of the month-to-month performance of the crushing and screening process is the most important part of the RBM life-cycle. It allows the author to be able to analyse and assess the results of the performance for the month in question. This recording process was part of the monitoring stage of RBM life-cycle approach.

Data sets were recorded on a hard copy production sheet exemplified in Figure 5, then the author would transfer the data, after checking the accuracy of the recorded data daily, onto a soft copy stored on the work computer. To ensure accuracy of the recorded data for the processed ROM in tons, there would be two separate recordings of the data by two of the operators stationed at separate points to limit possible communication or rigging of the recorded data.

This case study is based on the accuracy of the recorded data that will best capture the effects that are analysed. The recording of the diesel dispensed into each of the machines was recorded on the daily shift report as illustrated in Figure 5. To ensure accuracy, the fuel, measured in litres, was recorded and signed off by the operator who has been stationed to operate the machine at the time during the shift. The duty of the author was to ensure that each recording was signed off at the end of
each shift, which was when the machines were filled up in preparation for the next shift to commence.

The diesel bowser, which was a service truck with a one thousand, five hundred litre (1500 L) diesel tank, would be used to fill up the machines with diesel at the end of each shift, during the last hour of the shift. The diesel bowser operator utilised a recording booklet that also had to be signed off by the operator of the machine that is being fuelled. Although this was a double recording of the data, it was the method used on site to ensure, at the end of each month that the data was recorded accurately through cross-referencing the data sets.

The author used the captured data that operators recorded to double check the accuracy with the total amount of litres, per machine used in the crushing and screening process. If any deviation with the recorded monthly data was observed, then the author would check the original diesel bowser operator’s booklet and the original daily shift report to compare and to possibly find where the error could have been. The author would check each machine that has been recorded and the presence of a signature at each point the machines were filled during the shift, before the shift change.

Recording the total amount of diesel used in one-month’s operation and dividing that amount by the total amount, was how the author conducted the calculation of the diesel consumption per hour of the machines. The calculation is based on an average fuel consumption of the total duration. The fuel consumption during production is higher than the consumption while the machine is idling. This is due to the fact that the fuel consumption of a machine is higher when the revolutions per minute of the engine are higher.

The mine was located in Mpumalanga, near Witbank and the area experienced summer rainfall between the months of October to early April each year [7]. The positive effects of rainfall was that the moisture would limit the amount of dust that
the process releases into the atmosphere, but it would also cause the fuel consumption of the crusher and screen to increase due to the weight of ROM passing through the machines.

The crusher’s feeder bin is fitted with grizzlies that are designed to allow fine material to pass through to the product belt, preventing excess material from the crushing chamber. The wet material would build up on the sides of the feeder opening and ultimately reducing the size of the feeder opening, which would cause boulders that would normally enter into the chute, to be jammed at the opening.

The other disadvantage to the wet material was that it added weight to the material. The product belt of the crusher’s pulley would experience excess pressure due to extra weight of the excess water on the ROM and the operating system would automatically increase the revolutions per minute of the engine, which would increase the pulling power of the pulley. The increase in revolutions per minute would directly cause an increase in the crusher’s fuel consumption.

The screen’s steal sieves, also known as screens, were made of forty-by-forty millimetre (40 mm x 40 mm) openings as designed to achieve client specification. When the wet material would enter the vibrating screen box from the lifting conveyor, the material would experience greater resistance to pass through the sieve openings due to the moisture in the material, which increased the cohesion between the crushed ROM. This resulted in an increase in the amount of oversize material that was circulated back into the crusher, as it would not pass through the forty-by-forty millimetre (40 mm x 40 mm) openings.

The weight of the material was increased when wet and increased strain on the motors that operated the feeder belt and the lifting conveyor on the screen. The strain on the motors would put strain on the engine, which results in increased revolutions per minute. This increase in revolutions per minute of the engine
increased the fuel consumption. Appendix 6, in conjunction with Appendixes 2.1 - 2.7, illustrates the above analysis in a data format and in graphs.
Figure 4: Daily Shift Report

<table>
<thead>
<tr>
<th>Time</th>
<th>Opening hours</th>
<th>Closing hours</th>
<th>Down time</th>
<th>Time</th>
<th>Opening reading</th>
<th>Bucket</th>
<th>Average/hour</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>06:00</td>
<td></td>
<td></td>
<td></td>
<td>07:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>07:00</td>
<td></td>
<td></td>
<td></td>
<td>08:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08:00</td>
<td></td>
<td></td>
<td></td>
<td>09:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>09:00</td>
<td></td>
<td></td>
<td></td>
<td>10:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:00</td>
<td></td>
<td></td>
<td></td>
<td>11:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:00</td>
<td></td>
<td></td>
<td></td>
<td>12:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:00</td>
<td></td>
<td></td>
<td></td>
<td>13:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13:00</td>
<td></td>
<td></td>
<td></td>
<td>14:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14:00</td>
<td></td>
<td></td>
<td></td>
<td>15:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15:00</td>
<td></td>
<td></td>
<td></td>
<td>16:00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Machine:**
- Crusher LT1213
- Screen ST358
- FE950
- FE1966

**Shift Report**

**Source:** Madiba 2013
Metso Lokotrack LT1213 (Crusher)

The Metso Lokotrack LT1213 (Crusher) was a machine that had two control systems. One was used to move it around from one convenient place to the other and the other was for when it was in operation [16]. The crusher had a preprogramed maximum speed of five kilometres per hour (5 km/h) at its maximum two thousand one hundred revolutions per minute (2100 rpm) [16].

The preprogramed maximum speed was set low for safety reasons. The most common safety incidents related to the machine include cuts, limb injury, etc. which can be caused during movement of the machine [16]. The crusher product belt was manufactured to have a product belt height, from ground level, of three thousand two hundred and fifty millimetres (3250 mm) [16]. The grid deck height for the screen from ground level was three thousand five hundred millimetres (3500 mm).

When the crusher and screen were on the same ground level, the product belt of the crusher would not be high enough for the crushed ROM to be fed into the screen’s grid deck because the grid deck would be two hundred and fifty millimetres (250 mm) higher than the product belt coming from the crusher. Taking into account the thickness of the pulley at the end of the product belt, there would not be enough space between the bottom part of the pulley and the belt, for the rotation of the belt to occur with no friction between it and the grid deck on the screen.

The crusher had to be raised to allow for the product belt to feed the screen grid deck for the process to work as designed. During the first or last hour, dependant on the distance of the stockpiles from the machines, the crusher and screen would be moved to a location close to the ROM and finished product stockpiles.

The crusher would be raised by means of a deck/raised level, temporarily erected using one of the front-end loaders. The raised deck would be erected from the ROM that is yet to be processed. The level of the raised deck was constructed to be
approximately one meter (1 m) high. The measurement of the height was not required to be accurate because the purpose of the deck was to raise the overall height of the entire machine, which was mounted onto tracks, to a height that would allow the product belt of the crusher to be high enough to feed the screen’s grid deck without any contact between the two machines.

The width of the feed opening of the crusher was one thousand three hundred and twenty millimetres (1320 mm) and the height was nine hundred and eighty seven millimetres (987 mm) [16]. The throat of the crusher had a height of eight hundred and forty three millimetres (843 mm). The maximum diameter of the size of the boulder that could successfully enter through the feed opening and into the impactor chamber was as large as the openings permit, which was eight hundred and forty three millimetres (843 mm) [16].

The crusher was designed to operate while stationary. The crusher worked on a hammer system. It had rotating hammers that would impact the material against breaker plates to crush it to a less course material size [16]. Over time, the breaker plates would get worn and have to be replaced.

The crusher’s crushing process was automatically controlled by the operating system pre-installed by Metso. The system was designed to increase and decrease the engine’s revolution count, as and when the rotating hammers experienced resistance from the crushed material, normally this was when the feeder was full or the material was wet [16]. This automation increased and decreased the fuel consumption per hour of the crusher. For example, when coal is wet it gains weight due to the water particles. The increased weight in the coal added resistance to the rotating hammers, thus causing the operating system to automatically increase the revolution count on the engine to add more power to the rotation, which directly increased the crushing force and the fuel consumption.
The automated crushing process of the crusher made it virtually impossible to alter the preprogramed system in the efforts to reduce the fuel consumption. The operating system installed could be reprogramed, but that would have change the outcome of the pre-sets for the production rate and alter the number of fines in the material that was delivered to the screen [16].

The amount of ROM that was fed into the crusher was dependent on the operator’s competence in operating the feeding machine and the distance of the ROM stockpile from the ramp. The maximum ROM intake of the crusher was five hundred and forty tons an hour (540 tons/h). This maximum intake was measured on site by making sure the feeder bin was consistently full for a duration of an hour and weighing the amount of material that exits the machine on the product belt. This exercise was carried out three times and the average of the tonnages was calculated to five hundred and forty tons an hour (540 tons/h).

![Figure 5: Crusher Deck and FEL950 Ramp](image)

*Source: Madiba 2013*
**Metso Lokotrack ST358 (Screen)**

The Metso Lokotrack ST358 (Screen) was a machine that was used on site for the screening of the crushed ROM that was passed off the product belt from the crusher. The screen was made up of two decks of screens (steel diamond mesh nets), measuring forty millimetres (40 mm), which sieved the material to less than forty millimetres in diameter. The screens were made of steel and had to be checked daily for any damage to them due to the wear-and-tear caused by the coal, which could have lead to a breach in contract as the quality of the client’s demanded grading had to be maintained.

This machine was also mounted onto a track system that allowed the operator to move the machine around site by means of a control remote [17]. The screen decks were mounted onto vibrating grids that rotate causing a vibration effect on the angled screens, causing the less than forty millimetre (-40 mm) diameter material to pass through and retained material was passed onto the oversize belt [17]. The oversize belt returned the oversize material to the crusher to be re-crushed to less than forty millimetres in diameter [17].

The screen utilised mechanical motors to move the conveyor belts as to transport the material through the machine. The steel screens were connected to a rotating mechanism that caused a vibration effect [17]. The motor speeds had been preprogramed and the operating system did not allow for fluctuating speeds with the system while it was in operation [17].

The screen used an automated and preprogramed system during production. The diesel engine’s maximum revolutions per minute were two thousand two hundred (2200 rpm) [17]. This setting allowed for accuracy in the captured data as the operating system did not increase nor decrease the revolutions per minute, unlike the crusher.
CAT 950 H Front End Loader (FEL950)

On site the employees referred to this machine as the *Feeder* because it was used to feed the crusher with ROM from the mining pit. The FEL950 was fitted with a five cubic meter ($5 \text{ m}^3$) steel bucket used to scoop up ROM and feed it into the crusher’s feeder bin. The height of the feeder bin from the ground was four thousand six hundred and twenty millimetres (4620 mm). The maximum height that the FEL950 bucket could reach, when fully open was three thousand millimetres (3000 m).

The FEL950 was run by a one hundred and forty seven kilowatt (147 kW) diesel engine [8]. The maximum revolutions per minute of the engine were one thousand nine hundred (1900 rpm) [8]. The engine’s semi-automatic gearbox had the power to accelerate the loader up to a maximum forward speed of thirty-seven kilometres an hour (37 km/h) and a reverse maximum speed of forty kilometres an hour (40 km/h) [8]. The gearbox had been manufactured to a maximum of four gears forward and four gears in reverse.

To ensure that the FEL950 could effectively feed the crusher, a temporary ramp for the front-end loader had to be constructed so as to allow the loader operator to be able to raise the bucket to effectively feed the crusher. The ramp would be sloped at an angle not greater than forty-five degrees ($45^\circ$) to ensure that the slope was not too steep for the FEL950.

The FEL950’s diesel was consumed during three main stages of operation. The stages included having the FEL950 travel from the ramp to the ROM stockpile to scoop material and load it into the crusher so it may be processed. The stages were part of each ten-hour shift. The three stages were:

1. The first hour of the shift, after the operator had inspected the machine and filled out the pre-start checklist, the temporary crusher elevated deck and ramp had to be constructed close to the ROM stockpile,
2. Production, where the FEL950 was operated between the ROM stockpile and the crusher, and

3. This stage involved cleaning the site where ROM may have fallen over on the sides of the crusher’s feeder bin.

During these three stages, reducing the amount of distance that the machine had to move to continue to create consistent feeding into the crusher feeder bin could be the best solution to reduce the FEL950’s monthly fuel consumption. The distance from the ramp and crusher contributed to the fuel consumption, as the larger the distance, the further the FEL950 had to move to get to the material and the greater the speed it had to travel at. Idling inside a diesel engine also lead to incomplete combustion and emissions level and thus increasing the fuel consumption [21].

**CAT 966 H Front End Loader (FEL966)**

On site the employees referred to this machine as the 966, it was used to scoop the finished product from under the product belt of the screen and transport that material onto a stockpile, premeasured by the author on site. The FEL966 was fitted with a six point eight cubic meter (6.8 m³) steel bucket used to scoop up the finished product and transport it to the finished product stockpile area.

The height of each stockpile was an average of three and half metres (3.5 m). This was achieved by having the FEL966’s front tires being raised by climbing on the side of the stockpile, just enough to raise an extra meter on the total height of the bucket. The maximum height that the FEL966 bucket could reach, when fully open on a flat surface, was three thousand millimetres (3000 mm).

The FEL966 was run by a one hundred and ninety five kilowatt (195 kW) diesel engine [9]. The peak torque of the engine’s revolutions per minute, were one thousand four hundred (1400 rpm) [9]. The engine’s semi-automatic gearbox had
the power to accelerate the loader up to a maximum forward speed of thirty-seven kilometres an hour (37 km/h) and a reverse maximum speed of thirty-seven kilometres an hour (37 km/h) [9]. The gearbox was manufactured to a maximum of four gears forward and four gears in reverse.

To ensure that the FEL966 could effectively stockpile the finished product, the operator had to make sure that every time he raised the FEL966’s bucket to get the maximum height for the stockpile, he also ascended the two front tires up the side of the stockpile. The angle at which the slope of the stockpile occurred was estimated to be forty-five (45°).

The stockpile area measured one hundred and seventy five thousand square metres (175 000 m²) in area and had to house the ROM stockpiles, the RMC crushing and screening office container and stores container, finished product stockpiles and oversize boulders stockpiles. The oversize boulders stockpile was made up of ROM that was too large in size to fit into the crusher’s feed opening and therefore would not be able to fit into the impactor chamber where the hammers would crush the material against breaker plates.

The FEL966’s diesel was consumed during only one stage of the operation. The FEL966 had to move the finished product from under the product belt of the screen to the stockpile that had been pre-marked to size by the author.

During this stage, reducing the amount of distance that the FEL966 had to move to continue to create consistent movement of the finished product material, from under the product belt of the screen to the stockpile resulted in a reduction in the fuel consumption. The distance from the screen’s product-belt stockpile contributed to the fuel consumption, as the larger the distance, the further the FEL966 had to move to get to the stockpile and the greater the speed it had to travel at. See Figure 6.
The finished product stockpile under the product belt of the screen could not be allowed to increase to the point that the height of the stockpile reached the pulley of the product belt. The reason why it was vital for this not to occur was due to the strain that the material would add to the pulley. The increased strain would apply pressure on the underside of the conveyor belt, which would apply pressure on the motor that rotates the belt, ultimately causing damage to the coupling of the motor.

To avoid this situation from occurring, responsibility was put on the author and the operator. The author had to make sure that the distance of the finished product stockpile was not far from the screen, which would allow the operator to be able to travel from the finished product stockpile from under the belt of the screen to the stockpile, frequently enough to avoid the stockpile height from reaching the underside of the product belt. The operator’s duty was to make sure that movement of the process of moving material to a stockpile was not too slow, as it would cause the problem described above.

This amount of pressure to ensure the stockpile height does not get too high was a contributing factor to the fuel consumption. The finished product stockpile under belt of the screen would take an average of six minutes (6 min) to reach the underside of the product conveyor belt from the natural ground level. With the stockpile continuously growing and getting higher as the crusher is fed by the FEL950, the finished product stockpile where the FEL966 would have to move material had to be reasonably close to the screen.
Impact Study

Project quality management is a process of managing a project’s performance and finding ways in which to improve the processes of a project [1]. In this case study the author’s research is based on the impacts of poor quality control and quality management on the major running cost of the process, fuel consumption.
The impacts of poor quality control and quality management are measured on a month-to-month basis with the change in the fuel consumption being the basis of investigation.

The recorded monthly production in tons was never constant from a month-to-month basis due to two main factors that disfavoured the maximum possible production for the month. The factors were mechanical breakdowns on the machines and heavy rainfall that would temporarily stop all production on site due to safety reasons. The author has chosen to use percentages as a basis of measurement against the average fuel consumption per hour.

The financial affects were relative to the increase/decrease of the fuel consumption per hour. Appendixes 2.1 – 2.7 illustrate the average monthly fuel consumption for each of the machines in the crushing and screening process. The impact study is illustrated below on a monthly basis as to best exemplify the affects in a sequential timeline.

In October 2013 RMC’s project quality management system used on the crushing and screening process comprised of the following order of activities:

1. Recording of the production per shift,
2. Recording the amount of fuel dispensed per machine,
3. Recording the hours per machine to be used for maintenance planning and bookings, and
4. Reporting on the recorded data to the directors in a BOQ format.

The author’s realisation was that no efforts were made to analyse the data and evaluate possible process improvements. The effect of the poor quality control and project quality management is evident in Figure 7. The average fuel consumption from October 2013 to November 2013 increased by forty four percent (44%) for the FEL950 and twenty eight percent (28%) for the FEL966.
A non-structured stockpile area and excessive hauling distances triggered the increase in the fuel consumption. This prompted the need for a quality control system to be introduced by the author and a perfect opportunity for a research case study by using the changes in the recorded data as evidence of the affects.
After perusal of the machines’ fuel consumption, the author opted to implement the RBM life-cycle approach. The approach, adapting it to the project, involved analysis of the recorded results, crafting a possible solution, implementing it and once again analysing the achieved results. Repetition of this cycle, as suggested by the RBM life-cycle, would optimize the process and therefore the project. The author created a procedure of testing variations to the daily shift routines, the summarised results being:

1. Increasing the ROM stockpile size/height in the efforts of reducing the number of times the crusher and screen had to be moved into a more convenient operating position.

   The result was that the ROM stockpile would be successful in limiting the number of times the crusher and screen had to be moved from one place to the other in order for the process to continue well. The negative effect was the final stockpile area would be filled with two thousand ton (2000 ton) stockpiles, causing the front-end loaders to have to travel further distances from the crusher and screen. This impact evaluation proved to be unsuccessful due to the increased travel distances of the loaders, which increased the fuel consumption.

2. ROM stockpiled near the crusher and screen which remained stationary at one point of operation.

   Results of this strategy indicated that this posed a collision safety issue to the machine operators of the crushing and screening department, and the trucks transporting the ROM to be stockpiled. The area around the production machines would be saturated with final product stockpiles on one half and the other side consisted of ROM stockpiles. The area on the ROM side, once saturated, would not allow space for the trucks transporting ROM to turn
efficiently and the front-end loader that loads the crusher to operate concurrently.

This strategy also affected the fuel consumption negatively because once the fished product stockpile area was saturated, the loader would have to travel an extra distance to allow for the stockpiling.

3. Reducing the traveling speeds of the loaders.

The reduction of the speeds that the loaders were traveling at ended on a negative result. The FEL 950 loading-rate was reduced due to the increased time that it took for the loader to load the crusher, which caused lower production tonnages within a shift. The FEL 966 caused the under-the-belt stockpile to reach the pulling motor, causing the coupling to seize.

4. Creating two ROM stockpile areas on the boundary of the stockpile area.

This strategy ended up being the best alternative compared to the previous tactics that were tested. The loaders were able to travel from one side of the area to feed the crusher and stockpile, while the other boundary was being stocked with ROM from the pit by the trucks. Having the machines operating at different ends of the stockpile area reduced the safety risk of collision.

December 2013, illustrated by Appendix 2.3, reveals a forty four percent (44%) and twenty six percent (26%) decrease in the average fuel consumption of the FEL950 and FEL966 respectively. The FEL950 was utilised for a total of twenty-two hours (22 hours) and the FEL966 for a total of fifteen hours (15 hours). This indicates that December was a slow month with minimal production and the time for maintenance on the machines. The fuel consumption occurred mainly during the maintenance times where the machines were idling. Idling of a diesel engine consumes fuel, but not at the same rate as when the engine is in operation [19].
The impacts of using the RBM life-cycle approach, are clearly shown between the months of January 2014 and April 2014, see Figure 8. A solid RBM system is a life-cycle where results are the most important aspect of planning, monitoring and evaluation, reporting and on-going decision making to improve the system [2].

Figure 8: Fuel Consumption/Hour - April 2014

<table>
<thead>
<tr>
<th>Machine</th>
<th>Total diesel usage for April 2014 (L)</th>
<th>Average consumption per hour</th>
<th>Fuel Consumption (From Mar) (+) Increase (-) Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metso Impactor LT1213</td>
<td>7,775</td>
<td>34.865</td>
<td>-1.439</td>
</tr>
<tr>
<td>Metso Screen ST358</td>
<td>4,470</td>
<td>17.070</td>
<td>+0.190</td>
</tr>
<tr>
<td>L04 (CAT FEL 950)</td>
<td>6,225</td>
<td>16.591</td>
<td>-1.506</td>
</tr>
<tr>
<td>L05 (CAT FEL 966)</td>
<td>6,613</td>
<td>22.805</td>
<td>+1.376</td>
</tr>
</tbody>
</table>

Figure 8: Fuel Consumption/Hour - April 2014
Continuous improvement in the crushing and screening was covered on the basis that the cost to run the process could be reduced by reducing traveling distances of the machines to and fro the stockpiles. Analysis of the factors that influence the fuel consumption on the FEL950 and FEL966 reduced their fuel consumption, between November 2013 and April 2014, by an average of forty one percent (41%) and twenty percent (20%) respectively.
Conclusion

Project quality management refers to the processes and activities that are implemented on a project to satisfy the needs of the project objectives [1]. Project quality management is achieved by the successful implementation of a quality management system, through its policies and procedures with continuous process improvement undertakings throughout the project, as appropriate [1].

RMC’s project quality management system covered recording of data for reporting purposes only. It lacked the evaluation of recorded data in order to improve the process. Appendixes 2.1-2.2 demonstrate the affects of having poor quality control and project quality management.

The Results Based Management (RBM) life-cycle approach is, in summary, a three-stage approach; planning, monitoring and evaluation. The approach is a quality control mechanism and forms part of a project quality management system. A solid RBM system is a life-cycle where results are the most important aspect of planning, monitoring and evaluation, reporting and on-going decision making [2].

The author’s utilisation of the RBM life-cycle approach in the crushing and screening process of ROM resulted in the reduction of fuel consumption of the machines operated on site. The crusher and screen’s operating system was automated in such a way that the strain experienced by the machine was mitigated by an automated increase in revolutions per minute on the engine, thus increasing the power of the machine, but consequently increasing the fuel consumption.

The RBM life-cycle approach resulted in a forty one percent (41%) and a twenty percent (20%) average decrease in the fuel consumption of the FEL950 and FEL966, respectively over a period of seven months. The reduction resulted from the
implemented changes resulting from the evaluation of the recorded data from a month-to-month basis, by reducing their travel distances to and from the stockpiles. The most simple and often forgotten way to reduce fuel consumption is by reducing the distance travelled [19].

Appendixes 2.3 -2.7 illustrate the benefits of having a quality management system of evaluating and assessing the results, and implementing the change that reduced the fuel consumption. The results may not be tremendous, but it is evident of a positive result.

Through the continuous utilisation of the RBM life-cycle approach, RMC could continue to find ways and implement changes that could reduce the running costs of the crushing and screening process. The author suggests that RMC employ the RBM life-cycle approach as a project quality management system to continuously improve all their mining processes.
References


# Appendices

## Appendix 1: RMC Machine Information

<table>
<thead>
<tr>
<th>RMC - Crushing and Screening Machine Info.</th>
<th>Machine: CATERPILLAR (Loader)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model</strong></td>
<td>Lokotrack 1213</td>
</tr>
<tr>
<td><strong>Serial NO</strong></td>
<td>74715</td>
</tr>
<tr>
<td><strong>Year made</strong></td>
<td>2008</td>
</tr>
<tr>
<td><strong>Engine:</strong> CATERPILLAR</td>
<td></td>
</tr>
<tr>
<td><strong>Engine make</strong></td>
<td>C13</td>
</tr>
<tr>
<td><strong>Serial NO</strong></td>
<td>LGK11095</td>
</tr>
<tr>
<td><strong>Fuel capacity</strong></td>
<td>600 L</td>
</tr>
<tr>
<td><strong>Engine power</strong></td>
<td>310KW</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MACHINE: METSO (SCREEN)</th>
<th>MACHINE: CATERPILLAR (Loader)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Model</strong></td>
<td>Lokotrack ST358</td>
</tr>
<tr>
<td><strong>Serial NO</strong></td>
<td>R3581596</td>
</tr>
<tr>
<td><strong>Year made</strong></td>
<td>2009</td>
</tr>
<tr>
<td><strong>Engine:</strong> DEUTZ</td>
<td></td>
</tr>
<tr>
<td><strong>Engine make</strong></td>
<td>TDC2013 (L04 [Tier 3])</td>
</tr>
<tr>
<td><strong>Fuel capacity</strong></td>
<td>170 L</td>
</tr>
<tr>
<td><strong>Engine power</strong></td>
<td>167,7HP - 125KW @ 2200 RPM</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 2.1 – October 2013 Fuel Consumption Summary

<table>
<thead>
<tr>
<th>Machine</th>
<th>Total diesel usage for October 2013 (L)</th>
<th>Average consumption per hour</th>
<th>Fuel Consumption (From Mar) (+) Increase (-) Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metso Impactor LT1213</td>
<td>2,747</td>
<td>37.380</td>
<td>N/A</td>
</tr>
<tr>
<td>Metso Screen ST358</td>
<td>3,279</td>
<td>16.397</td>
<td>N/A</td>
</tr>
<tr>
<td>L04 (CAT FEL 950)</td>
<td>3,511</td>
<td>15.767</td>
<td>N/A</td>
</tr>
<tr>
<td>L05 (CAT FEL 966)</td>
<td>3,052</td>
<td>20.723</td>
<td>N/A</td>
</tr>
</tbody>
</table>

![Fuel Consumption/Hour Graph]

- Metso Impactor LT1213
- Metso Screen ST358
- CAT FEL 950
- CAT FEL 966
Appendix 2.2 – November 2013 Fuel Consumption Summary

<table>
<thead>
<tr>
<th>Machine</th>
<th>Total diesel usage for November 2013 (L)</th>
<th>Average consumption per hour</th>
<th>Fuel Consumption [From Mar] (+) Increase (-) Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metso Impactor LT1113</td>
<td>765</td>
<td>37.380</td>
<td>0</td>
</tr>
<tr>
<td>Metso Screen ST358</td>
<td>592</td>
<td>16.397</td>
<td>0</td>
</tr>
<tr>
<td>L04 (CAT FEL 950)</td>
<td>1,819</td>
<td>28.114</td>
<td>+12.347</td>
</tr>
<tr>
<td>L05 (CAT FEL 966)</td>
<td>1,466</td>
<td>28.633</td>
<td>+7.910</td>
</tr>
</tbody>
</table>
Appendix 2.3 – December 2013 Fuel Consumption Summary

<table>
<thead>
<tr>
<th>Machine</th>
<th>Total diesel usage for December 2013 (L)</th>
<th>Average consumption per hour</th>
<th>Fuel Consumption (From Mar) (+) Increase (-) Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metso Impactor LT1213</td>
<td>483</td>
<td>26.833</td>
<td>-10.547</td>
</tr>
<tr>
<td>Metso Screen ST358</td>
<td>179</td>
<td>9.421</td>
<td>-6.976</td>
</tr>
<tr>
<td>LO4 (CAT FEL 950)</td>
<td>270</td>
<td>12.442</td>
<td>-15.672</td>
</tr>
<tr>
<td>LO5 (CAT FEL 966)</td>
<td>316</td>
<td>21.208</td>
<td>-7.425</td>
</tr>
</tbody>
</table>

**Fuel Consumption/Hour**

- Metso Impactor LT1213
- Metso Screen ST358
- CAT FEL 950
- CAT FEL 966
### Appendix 2.4 – January 2014 Fuel Consumption Summary

<table>
<thead>
<tr>
<th>Machine</th>
<th>Total diesel usage for January 2014 (L)</th>
<th>Average consumption per hour</th>
<th>Fuel Consumption (+) Increase (-) Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metso Impactor LT1213</td>
<td>1,462</td>
<td>25.240</td>
<td>+2.407</td>
</tr>
<tr>
<td>Metso Screen ST358</td>
<td>674</td>
<td>14.042</td>
<td>+4.621</td>
</tr>
<tr>
<td>L04 (CAT FEL 950)</td>
<td>961</td>
<td>18.917</td>
<td>+5.475</td>
</tr>
<tr>
<td>L05 (CAT FEL 966)</td>
<td>1,090</td>
<td>27.182</td>
<td>+5.974</td>
</tr>
</tbody>
</table>

![Fuel Consumption/Hour 1](image-url)

**Fuel Consumption/Hour 1**
Appendix 2.5 – February 2014 Fuel Consumption Summary

<table>
<thead>
<tr>
<th>Machine</th>
<th>Total diesel usage for February 2014 (l)</th>
<th>Average consumption per hour</th>
<th>Fuel Consumption (+) Increase (-) Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metso Impactor LT1213</td>
<td>4,642</td>
<td>33.164</td>
<td>+3.924</td>
</tr>
<tr>
<td>Metso Screen ST358</td>
<td>2,518</td>
<td>17.129</td>
<td>+3.087</td>
</tr>
<tr>
<td>LO4 (CAT FEL 950)</td>
<td>3,185</td>
<td>19.004</td>
<td>+0.12</td>
</tr>
<tr>
<td>LOS (CAT FEL 966)</td>
<td>3,955</td>
<td>25.016</td>
<td>-2.166</td>
</tr>
</tbody>
</table>

Fuel Consumption/Hour

Minor Dissertation: The Benefits of Applying the Results Based Management Life-Cycle Approach to the Crushing and Screening Process of Run of Mine

By: Khaya Madiba
Appendix 2.6 – March 2014 Fuel Consumption Summary

<table>
<thead>
<tr>
<th>Machine</th>
<th>Total diesel usage for February 2014 (L)</th>
<th>Average consumption per hour</th>
<th>Fuel Consumption (From Feb) (+) Increase (-) Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metso Impactor LT1213</td>
<td>10,201</td>
<td>35.303</td>
<td>+3.139</td>
</tr>
<tr>
<td>Metso Screen ST358</td>
<td>4,777</td>
<td>15.880</td>
<td>-0.249</td>
</tr>
<tr>
<td>L04 (CAT FEL 950)</td>
<td>5,688</td>
<td>18.097</td>
<td>-0.907</td>
</tr>
<tr>
<td>L05 (CAT FEL 966)</td>
<td>6,660</td>
<td>21.429</td>
<td>-3.587</td>
</tr>
</tbody>
</table>

![Fuel Consumption Chart]

Fuel Consumption/Hour

Minor Dissertation: The Benefits of Applying the Results Based Management Life-Cycle Approach to the Crushing and Screening Process of Run of Mine

By: Khaya Madiba
Appendix 2.7 – April 2014 Fuel Consumption Summary

<table>
<thead>
<tr>
<th>Machine</th>
<th>Total diesel usage for April 2014 (L)</th>
<th>Average consumption per hour</th>
<th>Fuel Consumption (From Mar) (+) Increase (-) Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metso Impactor LT1213</td>
<td>7,775</td>
<td>34.865</td>
<td>-1.438</td>
</tr>
<tr>
<td>Metso Screen ST358</td>
<td>4,470</td>
<td>17.070</td>
<td>+0.190</td>
</tr>
<tr>
<td>L04 (CAT 950)</td>
<td>6,225</td>
<td>16.591</td>
<td>-1.506</td>
</tr>
<tr>
<td>L05 (CAT 966)</td>
<td>6,613</td>
<td>22.805</td>
<td>+1.376</td>
</tr>
</tbody>
</table>

![Fuel Consumption Graph](image_url)
Appendix 3 – Site Establishment Layout

Stockpile Area: 175 000 m²
Appendix 4 – Crushing and Screening Process Flow

Feeding (CAT 950H - Loader):
loader feeds Impactor feeder bin with ROM

Impactor (LT1213 - Crusher):
material crushed to -60mm and fed to screen by a conveyor system

Screening (ST358 - Screen):
crushed material screened to -40mm

Screening (ST358 - Screen):
-40mm stockpiled, oversize (+40mm) circled back to impactor

Under the Belt Stockpiling (CAT 966H - Loader):
-40mm material stockpiled at 2000ton stockpiles
## Data Set Summary (October 2013 - April 2014)

<table>
<thead>
<tr>
<th>Machine</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>January</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crusher</td>
<td>Screen FEL950</td>
<td>Crusher</td>
<td>Screen FEL950</td>
</tr>
<tr>
<td>Total Diesel Consumption for the Month</td>
<td>2,747</td>
<td>1,279</td>
<td>3,511</td>
<td>3,052</td>
</tr>
<tr>
<td>Total Monthly Production in Tons</td>
<td>43,962</td>
<td>16,792</td>
<td>2,920</td>
<td>9,973</td>
</tr>
</tbody>
</table>

### Additional Data

<table>
<thead>
<tr>
<th>Machine</th>
<th>FEL950</th>
<th>FEL966</th>
<th>Crusher</th>
<th>Screen</th>
<th>FEL950</th>
<th>FEL966</th>
<th>Crusher</th>
<th>Screen</th>
<th>FEL950</th>
<th>FEL966</th>
<th>Crusher</th>
<th>Screen</th>
<th>FEL950</th>
<th>FEL966</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Diesel Consumption for the Month</td>
<td>961</td>
<td>1,090</td>
<td>4,842</td>
<td>2,518</td>
<td>3,185</td>
<td>3,955</td>
<td>10,201</td>
<td>4,777</td>
<td>5,688</td>
<td>6,660</td>
<td>7,775</td>
<td>4,470</td>
<td>6,225</td>
<td>6,613</td>
</tr>
<tr>
<td>Total Monthly Production in Tons</td>
<td>9,973</td>
<td>37,512</td>
<td>80,167</td>
<td>71,319</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 6 – Witbank Average Monthly Rainfall Table

Witbank normally receives about 533mm of rain per year, with most rainfall occurring during summer. The chart below (lower left) shows the average rainfall values for Witbank per month. It receives the lowest rainfall (0mm) in June and the highest (105mm) in January. The monthly distribution of average daily maximum temperatures (centre chart below) shows that the average midday temperatures for Witbank range from 17.2°C in June to 25.8°C in January. The region is the coldest during July when the mercury drops to 1.7°C on average during the night. Consult the chart below (lower right) for an indication of the monthly variation of average minimum daily temperatures.

Move mouse over chart bars for monthly values

Average rainfall (mm)

Average midday temperature (°C)

Average night-time temperature (°C)

Certified Criminal Record

RCMP Canadian Fingerprinting Fast International Submission Apply Now!
Appendix 7 – Total Monthly Production in Tons (October 2013 – April 2014)
Appendix 8 – Project Quality Management Overview from the PMBoK