DRIVERS, MEASURES AND REWARDS FOR PRODUCTIVITY AND FINANCIAL IMPACTS/ BENEFITS IN THE MINING VALUE CHAIN AT BATHOPELE, KROONDAL AND MOTOTOLO MINES: AN INVESTIGATION OF IMPACTS FROM SHORT TERM PLANNING TO MILL

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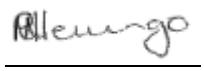
A project report submitted to the Faculty of Engineering and Built Environment, University of the Witwatersrand, Johannesburg, in partial fulfilment for the degree in Master of Science in Engineering (Mining).

Johannesburg, 2014

DECLARATION

I declare that this project is my own unaided work. It is being submitted in partial fulfilment of the requirements for the Degree of Masters of Science in Engineering at the University of the Witwatersrand, Johannesburg and has not been submitted before for any degree or examination at any other university.



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Signed on this 16th day of July 2014

ABSTRACT

Productivity is a measure of production efficiency and it is the rate at which input resources are effectively translated into outputs. There are several measures of productivity which are all broadly categorised as partial or total (multi factor) productivity depending on the parameters used in calculations. Several plan compliance metrics, advantages and disadvantages of outsourcing as well remuneration mixes also emerged from literature review. There is a need to understand ways of measuring productivity and improving productivity under changing economic conditions to ensure that the South African mining industry is competitive. This project illustrates the productivity trends at selected Anglo American Platinum Limited (Amplat) mines namely, Bathopele, Kroondal and Mototolo. The project further investigated the trends in market factors and establishes the correlation coefficients between reported measures of productivity and market factors. Such market factors include: the Republic of South African (RSA) and United States of America (US)' inflation rates, platinum price as well as the exchange rate (US dollar/RSA Rand). Amplat reported two categories of partial productivity, labour productivity and financial productivity. Fluctuating trends in productivity were observed for all three mines irrespective of the measure of productivity analysed. Fundamental causes of productivity differences between mines included: stoping width, relative rock density, grade, dilution, recovery factors (in the concentrators and smelters), metal ratios, mine call factor. There is a need to investigate productivity improvement by commodity to keep the mining industry competitive. It was concluded that labour availability and utilisation are becoming increasingly important, given the unionised nature of the mining industry.

DEDICATION

To my late father (Erasmus), mother (Rosamunde), siblings (Cecilia, Onesmus, Severina, Maria, Berhilde & Paulina), cousin (Joseph), nieces and nephews who supported me tirelessly. You are my blessings, be blessed.

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LIST OF SYMBOLS

m^2	square metres
t	tonnes
oz	ounces
%	percent
Rand	South African Rand
$	dollar

LIST OF ABBREVIATIONS

ABET	Adult Basic Education Training
Amplat	Anglo American Platinum
BIC	Bushveld Igneous Complex
CEO	Chief Executive Officer
LE	Latest Estimate plan
MFP	Multi Factor Productivity
MRM	Mineral Resource Management
PGMs	Platinum Group Metals
Pt	Platinum
RSA	Republic of South Africa
SRF	Short Range Forecast plan
TFPI	Total Factor Productivity Index
UG2	Upper Group 2 reef
US	United States of America also referred to as United States
USSR	Union of Soviet Socialist Republics

CHAPTER 1: INTRODUCTION

This Chapter is aimed at conceptualizing the research project. It is the starting point which gives an overview of the importance, locality, scope and other aspects pertaining to where, how and why this project was conducted. The Chapter starts with the rationale where the background of the study is given to justify the existence of the problem. The Chapter further discusses other variables relating to the problem as well as defining terms within the reference of the project. The Chapter will conclude with a brief introduction of subsequent Chapters.

1.1. Rationale

Platinum is a precious metal which is commonly used for industrial and investment purposes. However, unlike most other precious metals, due to the location of platinum reserves, production thereof is dominated by RSA. The Bushveld Igneous Complex (BIC) in RSA hosts over 70% of worldwide reserves of platinum group metals (PGMs) and contributes approximately 80% to global production of PGMs. The Bushveld is divided into two limbs: western and eastern limb which are dominated by the Merensky and Upper Group 2 (UG2) reefs respectively.

The BIC therefore provides RSA, and in particular the mining companies exploiting PGMs, with a comparative advantage. However, this advantage is offset by the fact that PGMs are supplied to global markets where prices are set on free market principles. Therefore, any comparative advantage in supply needs to be coupled with high production efficiency to ensure sustainable and competitive mining. Figure 1 shows the distribution of world platinum reserves whereas Figure 2 shows platinum production by location. However, the

shallow Merensky reef in the western limb has been mined extensively leaving current focus on the UG2 reef.

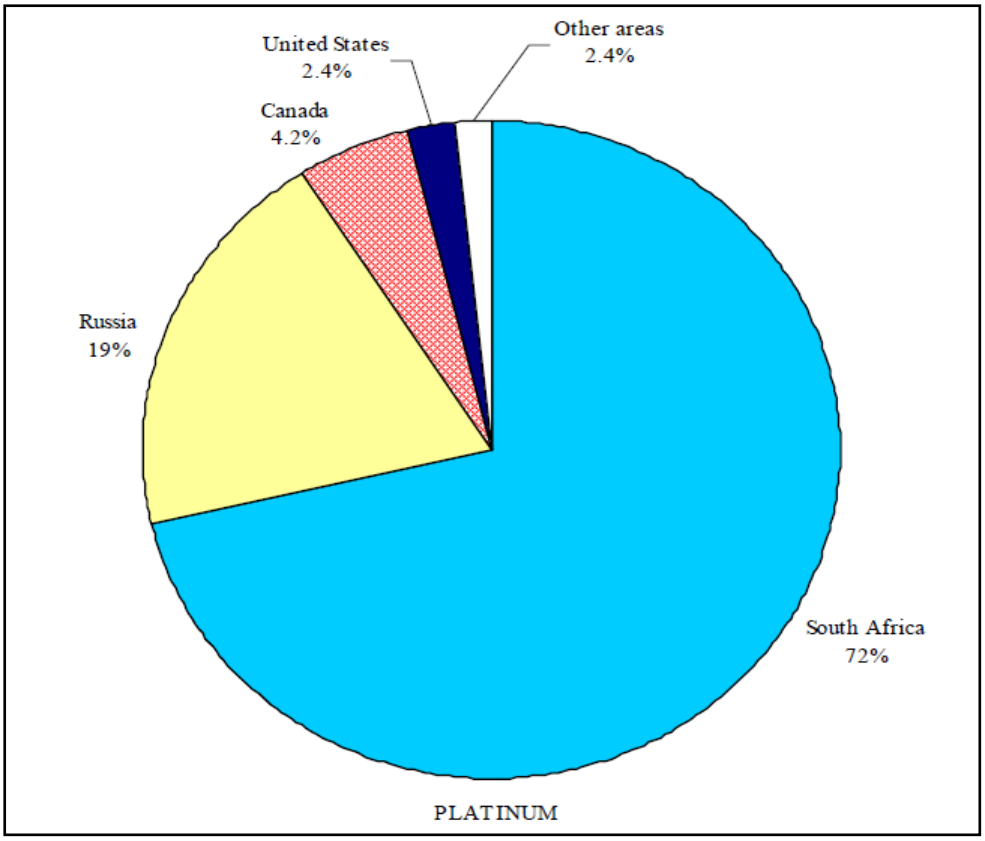


Figure 1: Distribution of world platinum reserves (Wilburn and Bleiwas, 2004)

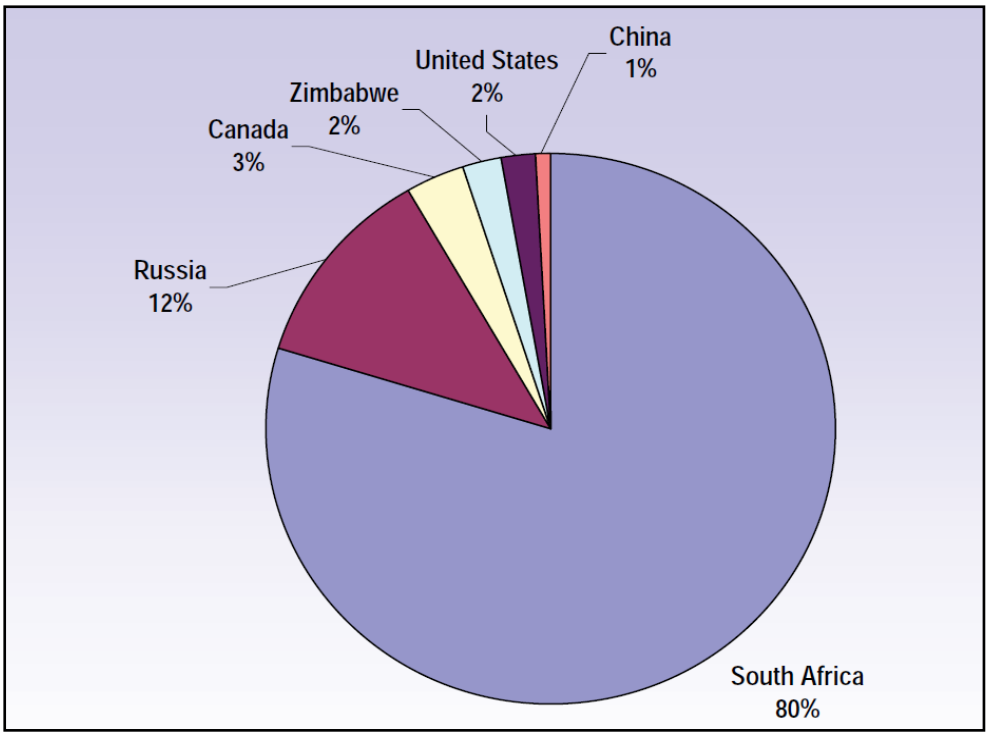


Figure 2: Platinum production by location (World platinum mine supply, 2006)

The two figures above emphasise the major role played by RSA in the global platinum supply. This means, platinum ought to be efficiently extracted. RSA has no direct control over platinum prices and since RSA supplies platinum to global markets, the RSA platinum industry needs to remain competitive in these markets.

Traditionally, underground mining of tabular, narrow orebodies was done by conventional methods, like scattered breast panel stoping with handheld pneumatic rock drills. Advances in technology as well as increased health and safety standards continually stimulate attempts to mechanise and automate mining. Notwithstanding these efforts, it must be understood that mining takes place under unique conditions which do not all favour full mechanisation nor complete automation. Hence the need to optimise and remain efficient within various constraints including those posed by the orebody capability.

Mining is land, capital, labour and energy intensive, while, platinum demand is driven by the need for auto catalysts. Continuous research is taking place in an effort to substitute platinum with cheaper alternatives. While this research has yielded some results, it has not proved possible to completely substitute platinum. Should these substitutes become available at a later stage then the platinum demand could slump depending on the ability of the platinum industry to remain competitive.

It is against this background that stakeholders in PGM production are continually concerned with mine management's ability to use inputs effectively to translate them into quality outputs. In essence this means close monitoring of effective utilisation of people, material and money to get maximum production of PGMs under given conditions, thereby, maximising profit.

Traditionally volume-based compensation has been used extensively to create a team environment with benefit-sharing to motivate employees. It can be argued that there is a need to reward performance, based on productivity, without compromising either the short or the long term value of the company. This means, there is a need for employees to understand how their performance is measured and rewarded, as well as understanding the role they play in their own productivity improvement and that of the company. The attitude of employees and their understanding of company goals (and its alignment with their personal goals) play a major role in productivity improvement and sustainability of competitiveness.

Against the above, the concept of productivity and other ratios which relate inputs to outputs are used in the business of mining. The depletion of accessible high grade ores and the prevailing economic conditions increase the need to focus on productivity. Therefore,

there is a need to understand the drivers of productivity as well as ways to measure them and successfully apply them to the reward system.

According to Richardson (1984), measurement of productivity is used by different groups of people with a variety of purposes in mind. Economists attempt to measure productivity to establish how efficiently and optimally resources are used in an economy, and examine competition between industries (Richardson, 1984). Corporate executives may wish to establish how a firm utilizes its input over time as compared to other firms (Richardson, 1984).

Mining is affected by both exogenous and endogenous factors (Camus, 2002). Endogenous factors are those within mining and can be controlled by mining companies/mines whereas exogenous are those that mines or even mining companies have no control over such as market factors. While production volumes can be controlled and subjected to endogenous factors, certain measures of productivity such as total or multi-factor productivity tend to smoothen out both, endogenous and exogenous factors to a certain extent. It is against these backgrounds, that mines and companies assess or should assess productivity to reward performance as well as improvement and identify areas of further improvement.

Within firms, department managers want to know the productivity of their employees and equipment for performance evaluation and payment purposes (Richardson, 1984). Bonuses are common rewards for meeting or exceeding production targets and/or productivity in the mining industry. Common production targets in narrow reef mining are metres advanced, square metres mined and tonnes broken. However, the question arising is: what are the fundamental drivers of productivity and how does a bonus affect an employee's motivation? This means, if one is not careful about how productivity is measured and

rewarded, it could promote wrong behaviour which among other things could compromise health and safety standards.

While this study does not involve interviewing employees to get their opinion on the bonus schemes, further research is required to establish the opinion of employees on the bonus. It will also be important to establish whether and how productivity is understood by employees at different levels.

Despite all that is said or written about productivity, there is a general lack of understanding of factors affecting productivity (Buzacott, 1985). The author believes (based on reports on productivity among mining companies) that there has been some improvement in understanding productivity since Buzacott's (1985) observation. However, the extent to which both reported and unreported measures of productivity are applied to the benefit of mining companies is limited. This assertion is based on observations made by the author during several mine visits; it was observed that some mines are still awarding bonuses based on traditional production measures rather than productivity. These traditional measures of performance worked very well in the era of high volume and high grade mining, but declining grades and squeezed profit margins require revisiting the basis for performance rewards.

As defined by economists, productivity is monetary output divided by monetary input. Output in mining conversely is often in terms of revenue or ounces of platinum refined while input is quoted in terms of total employees or total man-hours (Buzacott, 1985). Following this logic, it then follows that productivity should be increased by keeping the output constant and reducing the number of employees (Buzacott, 1985). However, given the intensity of mining, the question must be asked as to whether one can realistically

reduce the number of employees and still maintain the same output. There is therefore a need to investigate what the drivers for productivity are.

Production volumes moved do not necessarily add value because sometimes large volumes of waste are moved. Therefore, there is a need to think through a multi-factor (total) productivity measure to apply in a reward system when waste materials are moved as well as when health and safety standards are met, without compromising the value of the business. Value depression is not often considered when these rewards are given especially in economic boom times where commodity prices are high and sometimes even coupled with a weaker Rand against the US dollar.

Wilburn and Bleiwas (2004) noted that the appreciation of the Rand against the US dollar at that time affected the rate of implementation of various RSA expansion projects in 2001. Similarly, the strength or weakness of the Rand against the US dollar could seemingly impact productivity. While this is a possibility, there is a need to investigate and quantify the relationship between the exchange rate and productivity.

In summary, while measures of productivity provide some degree of production efficiency, it is affected by factors such as employees' working conditions and motivation; effectiveness of measuring tools as well as the reward system used. In addition to the financial ratios which are used to assess economic efficiency of the company, productivity remains the ultimate measure of production efficiency.

There is a need to investigate how productivity from short term planning to mill relates to accounting and economic ratios. Health and safety standards are being raised all the time. Thus, there is also a need to investigate and incorporate health and safety performance into

productivity. Moreover, mine planning is a function which translates corporate goals into operational objectives, thus there is a need to test mine plan compliance.

1.2. Objectives

Mining is a capital intensive industry which requires a large amount of upfront capital investment and well as large amounts for day to day running costs. However, there is also a big time lag between investment and return on investments. During the lag period and possibly during re-capitalisation of a mining project, capital productivity and total productivity could be negative. While this is a possibility, can it be quantified and can the overall benefits/impacts of productivity on the cashflows be quantified? It is against this background that this project is aimed at:

- Determining the factors/drivers that influence productivity in platinum mining.
- Analysing the current measures of productivity and how productivity is rewarded.
- Understanding the employees' specific working conditions and their ability to produce optimally within these conditions without compromising safety. What are the constraints within the system, can these constraints be eliminated or how can there be optimisation within these constraints?
- Comparing productivity in mechanised mines employing no contractors; only contractors and a mix of contractors and in-house employees.
- Determining the ratios between production bonuses and basic salaries. While bonus payments are used to motivate employees to achieve/exceed production targets, it can be argued that high bonus payments for production could compromise safety. Therefore question arising is: can safety be effectively incorporated into measures of productivity and rewards?

Evaluating the impacts of productivity rewards on cashflows under simulated, changing economic conditions to help assess the riskiness of productivity rewards is a subject of further research. This project will not develop general guidelines for productivity across the mining industry. However, further research in this area will help to simulate and suggest a reward system which caters for changing economic factors among other issues.

1.3. Statement of the problem

Productivity is the ultimate measure of production efficiency as well as a measure of the growth potential of a company. However, productivity drivers, measures and rewards need to be understood and modelled under changing mining and economic conditions. Moreover, there is a need to determine the correlation between productivity and financial performance and between productivity and plan compliance metrics.

1.4. Scope

The project will focus on evaluating the benefits and impacts of measures of productivity and rewards from planning (short term) to mill. This means the project will look at the following flow of processes: short term planning; drilling and blasting; loading and hauling; hoisting as well as transportation to the mill. In this context, loading and hauling refers to the movement of rock from the face to the stockpile or tip. Productivity is a measure of efficiency, but is it possible to relate and perhaps outweigh the financial impacts of productivity rewards with its benefits?

1.5. Background of mines to be studied

This project will look at how productivity is measured and rewarded at selected mechanised platinum mines and will include a study of measures of productivity reported in public reports. While some financial information is confidential and does not form part of public

reporting, the author was able to analyse financial information of one of the mines selected. The platinum mines studied were Bathopele, Kroondal and Mototolo.

Bathopele Mine is situated in the North West province of South Africa, near the town of Rustenburg and within the western limb of the BIC. The current infrastructure consists primarily of two decline shafts, namely East shaft and Central shaft (Anglo American Platinum Limited, 2011a). It is a fully mechanised operation that mines the UG2 horizon exclusively, at a current depth varying between 40 m and 300 m below surface (Anglo American Platinum Limited, 2011a). The mining layout is bord and pillar (Anglo American Platinum Limited, 2011a). Bathopele is 100% owned by Anglo American Platinum Limited (Amplat), and mining is done by in-house employees.

Also in the western limb of BIC, Kroondal Platinum Mine is a 50:50 pooling and sharing agreement (PSA 1) between Aquarius Platinum (South Africa) (AQPSA) and Rustenburg Platinum Mines Limited (Anglo American Platinum Limited, 2011b). The mine is managed by AQPSA and is situated in the North West Province of South Africa, approximately 10 kilometres outside the town of Rustenburg (Anglo American Platinum Limited, 2011b).

Current mine infrastructure consists of four decline shafts, namely, Bambanani, Simunye, Kopaneng and Kwezi shafts (Anglo American Platinum Limited, 2011b). It is a mechanised mine which exclusively mines the UG2 horizon between surface and 450 m below surface (Anglo American Platinum Limited, 2011b). The mining method is bord and pillar (Anglo (Anglo American Platinum Limited, 2011b).

Mototolo Platinum Mine is a 50:50 joint venture between the Xstrata SA (Proprietary) Limited and Rustenburg Platinum Mines Limited (Anglo American Platinum Limited, 2011c).

The mine is managed by Xstrata RSA (Proprietary) Limited, and the concentrator by Anglo American Platinum Limited (Anglo American Platinum Limited, 2011c). The mine is situated in the Limpopo Province of South Africa, approximately 30 kilometres west of the town of Burgersfort (Anglo American Platinum Limited, 2011c). It forms part of the eastern limb of the BIC.

Current mine infrastructure at Mototolo consists of two decline shafts, namely Lebowa Shaft and Borwa Shaft (Anglo American Platinum Limited, 2011c). It is a fully mechanised mine which exclusively mines the UG2 horizon at a depth of between surface and 450m below surface (Anglo American Platinum Limited, 2011c). The mining method is bord and pillar (Anglo American Platinum Limited, 2011c).

1.6. Importance of the study

Mining is purely aimed at extracting the valuable content of mineral deposits from host rock in the most effective and efficient way. Profitability in mining is affected by various factors including some over which the mining companies have no control such as, exchange rate and metal price. Therefore, it is important to observe and give attention to those factors that can be controlled. Moreover, although market factors cannot be directly controlled, it is also important to operate optimally within these market constraints. According to Camus (2002), failure to give attention to the unique economic principles that govern the exploitation of mineral resources and the application of these principles to the management of mines stands out as the crucial component out of various other causes that lead to dismal performances of mining operations.

The need for the platinum industry expansion in recent times highlights the supply pressures that are created by an increase in global demand for PGMs. This supply deficit

calls for an increase in production, thereby increasing the production costs. The strengthening of the rand against the dollar erodes the Rand-based revenue and increases the dollar-denominated borrowings which highlight the importance of the exchange rate as determined by global markets. At the time of the study, despite a good commodity price, the Rand basket price of platinum was on a downward trend as a result of a strong rand to US dollar exchange rate.

The project will help in understanding ways of measuring productivity and rewarding productivity under changing economic conditions without negatively affecting cashflows, thus keeping the mining industry competitive. Understanding productivity will further aid in establishing measures and rewards which are not in conflict with a company's strategic goals including health and safety standards. The mining industry is different from say manufacturing companies in that no two mining projects are similar. On this basis, further work on the project will also establish measures of productivity and rewards for other commodities to suit their own dynamic environments.

1.7. Definition of terms

While some terms will be defined in the appropriate sections where they are used, some terms frequently used in this project are defined as follow:

Budget plan: The first short range forecast plan (SRF) determined six months prior to mining (Angelov & Naidoo, 2010).

High platinum price: The highest platinum price recorded within specified time period.

Low platinum price: The lowest platinum price recorded within specified time period.

Short term planning: Angelov and Naidoo (2010) stated that short term planning applies to a one-year period within a single business cycle and it is day-to-day scheduling of production as well as plant requirements

Strong Rand value: The lowest exchange rate recorded within specified time period.

Weak Rand: The highest exchange rate recorded within specified time period.

1.8. Subsequent Chapters

This report is divided into six Chapters; Chapter 1 discussed the existence and relevance of the project. Chapter 2 reviews literature on productivity, mine planning and contractor mining as well as salaries. Chapter 3 outlines and describes the process followed to collect and analyse data. Chapter 4 summarises and compares production data and productivity. Chapter 5 briefly discusses short term planning plan compliance and an analyses remuneration mix. Chapter 6 provides a summary of findings and recommendations.

CHAPTER 2: PRODUCTIVITY ALONG THE MINING VALUE CHAIN

This Chapter is aimed at understanding the concept of productivity and how it is applied in other countries and companies. It is an evaluation and discussion of selected literature published on productivity, mine planning and mine valuation. These articles were selected in relation to the breakdown of the project objectives, the sub-sections are therefore according to the same breakdown. This Chapter further provides an understanding of the past, current and possibly future market conditions (platinum price and exchange rate) and their possible influence on productivity and cashflows. From this Chapter, an idea of what data needed to be collected as well as an ideal data analysis strategy was established.

2.1. Definition of productivity and how it is measured

South Africa has world class mineral deposits. It has been stated that its BIC hosts several Platinum Group Metals and other metals. In addition its Witwatersrand complex hosts the world's largest known gold resource. However, the available deposits are getting deeper and now require more effort to extract. Regarding PGM's, the drop in ore grade due to an increase in the amount of UG2 mined, squeezes the profit margin if extraction is not optimal.

An extremely important responsibility of mining in RSA is to grow the economy. Therefore, it is important to efficiently extract minerals in order to make a profit and remain in business. Furthermore, platinum is fungible (this means an ounce of platinum from Bathopele is the same and cannot be differentiated from an ounce of platinum from any other mine) and is traded on an international market, with the need to remain competitive in these markets. Against this background, it is important to be able to measure efficiency and weigh it against some sort of benchmark which could involve an industry analysis or a time analysis.

Companies often compare themselves with their competitors using cost curves and a desire to be in the lower quartile of the cost curves. There is a need to investigate the extension of the same concept and establish other productivity curves. In addition to the financial ratios which are used to assess economic efficiency of the company, productivity remains the ultimate measure of production efficiency. Productivity is defined and measured in various disciplines including accountancy, economics, engineering and operations research (Rogers, 1998).

Although productivity is defined and measured, companies rarely include productivity in their public reports. This practice is partly caused by traditional accountancy which has been concerned more with the interest of holders of debts than with those who want to know how the company can grow and prosper (Strassman, 2004). This means, companies were more concerned about financial risks, such as the risk of being liquidated. It is against this background that the emphasis in periodical reports has been on accounting ratios.

Strassman (2004) further argued that, companies which reported productivity had done so in terms of revenue per employee, a measure he described not only misleading but also inconclusive. This observation is analogous with Bureau of Labour Statistics (2011; p4):

"*Although the labour measures of productivity relate output to hours of all persons in an industry, they do not measure the specific contribution of labour or any other factor of production. Rather, they reflect the joint effects of many influences, including changes in technology; capital investment; utilization of capacity, energy, and materials; the use of purchased services inputs, including contract employment services; the organization of production; managerial skill; and the characteristics and effort of the workforce.*"

Commodity prices have been observed to have cyclic behaviour where periods of economic boom as well as economic depression were noted in the past. Moreover, the mining industry is shackled with regulatory constraints, restrictive work rules and high labour costs requiring mine operators to reduce costs and improve productivity without overflowing the markets (Doepken, 1983). While it is still important to keep the interest of the holders of debt, it is also necessary to define and consistently measure productivity. Hence, there is a need to investigate how productivity from short term planning to mill relates to accounting and economic ratios.

There are several financial ratios, ranging from earning per share (EPS) to market capitalisation. However, most of these are calculated at corporate level. Further, detailed work is necessary to investigate the relationship between productivity and all financial/economic ratios. Based on the level of this project and availability of data, financial performance in this project will refer to the operating margin. This metric is reported in the public domain and was considered from 2007 to 2011 (both years inclusive) and compared to: 1) productivity; 2) platinum price trend; and 3) the exchange rate during the same period. The type of measures of productivity to be used in this comparison depended on the prominent measures used by the mines under study.

In broad terms, productivity is the ratio of output to input (Rogers, 1998) or more specifically, work productivity can be regarded as the ratio of enterprise output and input (Karna, 2007). The inputs and outputs differ from industry to industry, among companies within the same industry and even among departments. This ratio can be calculated by looking at either some or all production inputs. On this basis, two categories of productivity are defined, partial and total productivity. According to Oraee, Hossein, Soltani and

Amirafshari (2010) partial productivity describes the ratio of output to each input, including manpower, capital and energy whereas total productivity is the ratio of output to sum of inputs.

The decision on whether to look at partial or total/combined productivity can be based on the purpose for which productivity is to be calculated. For example, wage negotiators may find it useful and simpler to look at partial productivity, in terms of cost per unit of labour. Either way, Karna (2007) suggests that the chosen ratio is meant to be simple for two reasons: 1) finding facts and knowledge can be difficult and 2) validity of the knowledge is difficult to define. While economic/financial ratios are used in investment decisions, if measured properly, measures of productivity can aid in day-to-day decisions such as improving the process or changing equipment or the mining method.

The mining industry is changing and some of those changes are changes in the expectation of investors and increased global competition. On this basis, several attempts have been made to measure and quantify production efficiency to aid in making sound decisions. According to Green (1984), efficiency changes can be measured by an index of total factor productivity (TFPI). The following equation was used for gold mining (Green, 1984):

$$A_1/A_2 = \left[\frac{Q2/L2}{Q1/L1}\right]^{SL} \left[\frac{Q2/K2}{Q1/K1}\right]^{SK} \left[\frac{Q2/E2}{Q1/E1}\right]^{SE} \left[\frac{Q2/M2}{Q1/M1}\right]^{SM}$$

The above equation comes close to the time series analysis of financial statements of a company where A_1/A_2 measures relative efficiency between two points in time, 1 and 2. S signifies the shares of the different inputs: labour (L), real capital stock (K), and energy used in production (E) whereas Q signified the output (Green, 1984). In the case of gold, Q was

measured in ounces of gold produced and this was done to automatically include the influence of changing grade in the TFP index (Green, 1984).

Green (1984) further argued that, in this type of analysis two influences are measured. First, changes in partial productivity indices, i.e. Q/L, Q/K etc are determined; these are the directly observable influences on productivity. Second, an unexplained residual (A1/A2) is estimated. The latter measures the difference between the growth in inputs and the growth in real output. This equation involves taking several measurements for both output and inputs.

Various difficulties may be encountered in taking these measurements. Rogers (1998) identified two of these difficulties encountered to be whether output should be measured in terms of gross or partial value added and output quality may increase over time with static unit prices. The output is something that is produced (in mining, minerals) and should be calculated in physical units such as tonnes or monetary units such as dollars. Standard uses for productivity calculations are their use in estimation of efficiency and/or profitability as well as aiding in optimum allocation of resources (Oraee et al, 2010). Productivity is measured for various purposes including (Oraee et al, 2010):

- Strategic, in competitive markets for survival and/or improvement.
- Technical, for verifying performance of various divisions.
- Planning, to verify profit/loss and the necessary decisions.
- Management, for development or change in kind of activities.

Measures of productivity appear to be quite simple, but this is just a misconception (Oraee et al, 2010). Productivity involves the effective use of all production factors and can be time

dependent. Output measurements in mining can be production tonnages/ ounces or even the revenue/profit. This means productivity directly or indirectly relates to production trends, inflation as well as exchange rate. The challenge is to eliminate as many operation-specific as well as market influences as possible. In line with major mining inputs three types of partial productivity are classified:

- Manpower productivity in which manpower is measured either in working hours or number of workers (Oraee et al, 2010). Taking into account the level of education, technical knowledge, expertise, service records, and similar effect on labour cost (Oraee et al, 2010). The efficiency and therefore the cost of inexperienced labour is far different from that of skilled labour (Oraee et al, 2010). Apart from efficiency, salary differences also make the cost of manpower input market-dependent. Questions arising are: How are salaries adjusted in response to inflation; how are bonuses determined and how do bonuses relate to prevailing conditions? Against these backgrounds, if labour costs are considered in calculations of productivity, a base index is required which is not easy to calculate.

- Energy productivity which takes account of the cost of energy (electrical/air power/fuel). According to Oraee et al (2010), the cost of energy is neither dependant on variation of market prices nor on the supply and demand (Oraee et al, 2010). It is therefore important to determine the correlation between the energy productivity and TFPI. While it is beyond the scope of this project, further research in this area could involve determining factors affecting energy costs and their relationship with the market conditions.

- Capital productivity which accounts for buildings, machinery, equipment and the amount of reserves at a particular point in time (Oraee et al, 2010). The fact that maintenance, repairs as well as depreciation of capital goods have to be considered makes calculation of this input difficult. This project focuses more on understanding productivity trends and measures of productivity. However, further work should involve the whole mine operation as well as increasing the number of operations within the company to increase validity of results and confidence to generalise findings.

2.2. Application of measures of productivity

Productivity is a very important basis of competitiveness that companies in the mining industry can control. Hence, critical questions to be considered include:

- How productive are platinum mines compared to other hard rock mines?
- How does productivity vary by industry sector?
- How productive are the South African mines compared to those in other countries?
- What are the trends in productivity change, what are the fundamental causes of productivity trends and what changes are foreseen in the future?

To answer these questions, there is a need for measures of productivity that are reliable and can be understood by those studying the industry's problem. These measures should also be understood throughout the company (from manager to the labourer). Although mining projects are capital intensive, the long life of these projects enables enough time to recover the capital. However, within the life of a mine, management and employees change

continuously. On this basis it is also important that measures of productivity are generally easy to understand for relaxed continuity when new employees come into the company.

Industry continues to rely on traditional partial measures of productivity, which present an incomplete picture and which may be misleading when used as the basis for policy decisions. Ideally, total productivity would give a complete picture and is meant to take all factors into consideration. However, in practice there are several difficulties associated with measuring productivity (Richardson, 1984):

- Measuring output and various input in common units.
- Physical units are not directly comparable and a common measure should be identified.
- If monetary units are selected, valuation is a difficult and complex issue.
- It is difficult to determine quantities and values for intangible outputs, such as service or quality, and inputs such as technology and management.

These measurement problems are often further compounded by a variety of external factors which may distort the results obtained (Richardson, 1984). For example, accuracy in estimating environmental conditions and travelling time also pose problems. Moreover, changes in ore grade or variations in capacity utilization may significantly affect the apparent productivity of mining operations. A variety of measures have been developed in an attempt to overcome these problems. These can be classified along two dimensions relevant to the problem at hand: By level of aggregation, e.g. industry, firm, and department; and by type of measure, e.g. complex, total or partial (Richardson, 1984). The latter has been discussed in the previous section; this section briefly looks at productivity by level of aggregation.

Industry Measures: In the industrial sector, the common measure of productivity has been output per man-hour worked (Richardson, 1984). For statistical reporting by government agencies in the United States and Canada, this measure is derived by dividing sectoral or industry gross domestic product by the corresponding hours of all persons employed (Richardson, 1984). Although this measure has the advantage of simplicity, it is subjected to flaws affecting partial productivity. This calculation is based on the total number of hours paid for, while there are two major measurements which need and should be considered: labour utilisation and labour productivity (Aljuhani, 2002).

Furthermore, this measure often fails to make adequate adjustment for changes over time (Richardson, 1984). These changes include, but are not limited to: substitution of capital for labour and technology change (Richardson, 1984). As a consequence, market price increases or other changes may result in apparent productivity gains. Since prices are quoted in US dollars, this apparent increase in productivity could be reasonably high especially when an increase in commodity prices is coupled with a weak RSA Rand.

While apparent productivity gain is a possibility when commodity prices are high, can it be tested with real data? Four scenarios need to be tested: 1) high commodity prices, weaker Rand; 2) high commodity prices, strong Rand; 3) low commodity prices, weaker Rand; and 4) low commodity prices, strong Rand. This scenario testing requires detailed relationships (regression analyses) between these variables and is out of the scope of this project.

At sector and industry levels of aggregation, capital and labour are the two most widely investigated factors (Richardson, 1984). It is also important to investigate how adjustments are made in calculating financial ratios and whether one could adopt a similar approach when measuring productivity. At sector and industry levels of aggregation it is therefore

important to consider and base decisions on total factor productivity. According to Richardson (1984), total factor productivity (A) at a point in time is obtained by applying appropriate weights (W1 and W2) to the capital (K) and labour (L) inputs, as shown below:

$$A = \frac{V}{(W1 * K + W2 * L)}$$

V in the above equation signifies output, for example tonnes broken or milled. The above equation needs to be used to test mining productivity using the mining cost breakdown (drilling, blasting, loading, hauling, and labour) and if possible capital costs but otherwise capital costs can be excluded. Richardson (1984) further argued that, the impact of technological and managerial changes can be inferred from this approach by examining changes through time. The geometric index of productivity growth (G) can be obtained. Although this index can be useful over long periods of analysis, it is not further investigated in this project. However, further research could explore how to adjust this equation to form a unique base point for platinum mining, gold mining and possibly a general base point for hard rock mining.

The Firm Level: Profit and return on investment are the most widely used measures of corporate performance. However, they are not measures of firm productivity or efficiency. Rather, profit is a residual, and if it measures anything, it is the effectiveness of the firm in meeting its goals and objectives (Richardson, 1984). Consequently, there is continuing search for relevant measures of productivity for individual firms. In this context, firm refers to a single mine operation. However, due to time constraints, this project will only look at part of the value chain.

At firm level, tonnes per worker-hour, revenues per dollar of invested capital and tonnes of annual capacity per investment dollar remain the most common standards of labour and capital productivity in the mining industry (Richardson, 1984). Several comprehensive measures of productivity have been developed for use at firm level, the most quoted index is by Craig and Harris (1972-1975) (cited in Richardson, 1984). Their index considers total factor inputs consumed in producing specified output. A base year is selected which characterizes the normal corporate pattern for input costs and selling prices. These are then converted to constant dollar terms to eliminate the effect of inflation (Richardson, 1984). The index developed, has been used to measure changes in productivity within firms, but is not useful for comparison purposes (Richardson, 1984).

A more complex system of managerial control ratios to measure productivity has been proposed and applied in practical situations by Gold (1979) (cited in Richardson, 1984). Gold pointed out that firms do not exist to maximise a set of physical outputs relative to a given set of inputs (Gold 1979, cited in Richardson, 1984). The argument is, the firm should be rather viewed as a linkage system, tying physical measures of productivity to managerial and financial criteria such as sales growth and return on investment.

Departmental and Sub-unit Analysis: Measures of productivity at levels of aggregation lower than the firm are frequently required for payment purposes, especially where bonuses are used (Richardson, 1984). A variety of measures, many of them operation-specific, have been developed to measure productivity for these purposes. Most commonly, these are expressed in terms of output per man-hour (or man-shift) worked. Other partial measures of productivity include metres of advance per shift, equipment availability and utilisation, and mineral recoveries.

These partial measures are often used as the basis of inter-firm productivity comparisons, since indexes and complex measures are difficult to use for this purpose (Gold 1979, cited in Richardson, 1984). Unfortunately, when applied in this way these measures as well as direct comparison can be misleading because of intervening variables (Richardson, 1984). For example, comparisons of tonnes of ore per man-shift at different mining operations may fail to capture the impact of different mining methods, ground conditions, or equipment used. This means ergonomics plays an important role in labour productivity and consequently on total productivity. It is against this background that the researcher will observe the working conditions at the different mines.

In mining, because of the relatively standard form of commodity products, cost per unit of final output (tonnes of concentrate or metal not tonnes of ore) is frequently taken by managers as an overall indicator of productivity and competitiveness (Richardson, 1984). However, there is a need to investigate which of these indicators if any has taken account of the dynamic nature of mining and can be used as a benchmark.

Most international studies of mining industry performance use this measure to rank producers. However, since this measure taken alone can be quite misleading (due to variation in grade, mining method, equipment etc.) a variety of other measures are needed to complete an overall picture. While this is a fact, can the needed measures be identified and can they be measured, if not what is the alternative?

2.3. Drivers of productivity

In terms of the productivity types discussed above, productivity drivers are those production factors which affect the inputs and/or output. For example, manpower productivity is affected by travelling time to the workplace (stope face), operator efficiency, mechanical

availability of equipment and non-input factors such as technological progress (Syed & Grafton, 2011).

Unlike other sectors, in mining an increase in inputs does not necessarily increase the output. Syed and Grafton (2011) attributed this anomaly to two main factors: 1) the lags in output associated with capital investments and 2) the fact that mining is based on the size and quality of the ore bodies. The latter of these factors means that when mineral prices are high, mining companies are profitably able to extract lower grades ores and more costly ores (Syed & Grafton, 2011). This further means that high commodity prices could cause high apparent productivity. If real productivity is not calculated, bonuses could be given on the basis of apparent productivity and this practice could have an adverse impact on cash flow.

Although factors which affect inputs to productivity may also indirectly affect the output, there are other factors which directly affect the output. In general, factors affecting productivity and profitability include but are not limited to:

- Revenue received from product sales, which is controlled by the world market (Storrar, 1981). However, the concern here should be how to optimise productivity and productivity rewards within these market constraints. Platinum is traded on international markets where its price is quoted in US dollars per ounce. This means, platinum prices are affected by the US inflation rate among other factors.

- Working costs are the main debits which the mineral asset needs to pay for (Storrar, 1981). Therefore unit costs as measures of productivity need to be kept minimal without compromising production output. Production costs are in Rands and are

affected by the South African inflation. However, imported equipment and/or parts are affected by the foreign currency, inflation and the exchange rate thereof. While a weaker Rand assists the industry, because higher revenues (in Rand terms) are realised, it causes higher expenditure on imported equipment and materials.

- Efficiency factors such as percentage recovery and mine call factor. These are indicative of recovered and unrecovered mineral product (Storrar, 1981). These are directly proportional to productivity growth, provided that the inputs are unchanged. This means increasing throughput would ideally increase productivity. However, given the dynamic nature of mining, this relationship may not always be true.

Although the scope of this project ends at milling, further research to investigate any relationship between the Mine Call Factor (MCF) and productivity is required. Storrar (1981, p12), defined the MCF as "the ratio, expressed as a percentage, which the specific product accounted for in the recovery plus residue bears to the corresponding product called for by the mine's measuring and valuation methods." Specific product accounted for in the recovery is an output of measuring and valuation methods used. Therefore, the MCF is a measure of efficiency and defining its relationship with other measures of productivity would also help in establishing metal accounting throughout the mining value chain.

- Technological change will increase the TFPI by increasing the efficiency of output per unit input (Green, 1984). This is proven in coal mining, which is highly mechanised relative to hard rock underground mining. The use of continuous miners, which is currently coupled with continuous haulage in coal mining minimise the effect of

human factors on productivity such that productivity is more reliant on the availability and utilisation of the continuous miners. Felske (1971) cited by Wojciechowski (1984) described new product development as the only direction in which Canada has a real technological advantage and the only direction for significant economic gains for the industry.

- Economies of scale influence the relationship between inputs and outputs especially over the medium to long term (Green, 1984). For example, a large mining operation may move the firm to a lower point on its long-run average cost curve. This is because the high operating costs are offset by large volumes of production. The positions of the three mines (involved in this study) on cost curves will be determined from 2007 to 2011. This will merely be to enable comparison with trends in productivity and prices.
- An improvement in human capital will increase economic efficiency. A skilled and experienced workforce can obviously improve the quantity of output per unit of input (Green, 1984). Poor labour skills and negative attitudes can be significant sources of productivity problems, although management is responsible for correcting these attitudes (Wojciechowski, 1984). Labour tends to bear the economic brunt in bad time and it would be appropriate that management extend appreciation of labour into the good time with equal enthusiasm (Wojciechowski, 1984). Gain-sharing programmes should be based on productivity improvement and prescribed work goals, not on corporate or even mine profits (Wojciechowski, 1984).
- Organisation can affect efficiency. A change in the organisation of an industry, such as greater integration of existing individual production processes, may improve productivity (Green, 1984). Increasing for example, burden and spacing would

reduce unit drilling costs, but poor fragmentation may impact on the downstream processes such as milling. Therefore, it is important to consider the whole mining value chain especially when rewarding productivity. An improvement in one partial productivity measure may have short term benefits, while sterilising long term benefits.

- Although marketing is a downstream activity and may seem somewhat removed from productivity as measured by tonnes per man-shift, it is clearly part of the overall productivity picture of the industry (Wojciechowski, 1984). Improved sales of platinum and by-products improve the return on capital and other inputs.

  Wojciechowski (1984) further argued that the emergence of new producers, changes in consumption habits, substitution, restriction to free trade through international agreements and other trends must be understood in terms of their long term implications for prices and markets for Canadian minerals. While this is important in understanding and balancing supply and demand, it is important to investigate how to match productivity rewards with prevailing conditions. One possible solution is to continually establish productivity curves rather than cost curves.
- Change in mining methods can be beneficial and influence productivity. At Inco's research mine, adoption of a vertical retreat mining method has led to reduction in underground costs by as much as 80% (Wojciechowski, 1984). Productivity was also greatly improved, regardless of the way it was measured (tonnes per man-shift, operating cost per tonne, operating and capital cost per tonne) (Wojciechowski, 1984).

- Although the age of a mine does not directly affect productivity, there are certain old mines which operate at higher levels of productivity than newer ones and vice versa (Clatworthy, 1994). Older mines tend to operate at greater depths where the transport, ventilation costs can be quite high, but these could be offset by complete recovery of capital.
- Clatworthy (1994) also noted that the shaft layout system affects productivity. The location of shafts in close proximity to the areas where production takes place, can save on overall travelling time and therefore increase the effective shift time. Other factors affecting productivity as noted by Clatworthy (1994) are: development layout, stoping layout, effective shift time and production rate.

The labour measures of productivity used in industry describe the relationship between industry output and the labour time involved in its production. They show the changes from period to period in the amount of goods and services produced per hour. A key driver of labour productivity is the capital intensity of production, measured as the capital-labour ratio (Bradley & Sharpe, 2009). The capital-labour ratio is defined as the amount of capital available for each worker to work with. An increase in capital intensity means each worker has more capital to work with (Bradley & Sharpe, 2009).

2.4. Short term planning and compliance

Mineral resources are the principal assets in mining from which value is derived. Mining projects are capital intensive and risky, thus different stakeholders expect different returns from these projects. Therefore, the company's ability to manage capital investment effectively, ensuring acceptable stakeholder returns within an overall strategic context is central to its success (Smith, Pearson-Taylor, Anderson and Marsh, 2007).

Smith et al (2007) further argued that, the effective selection and implementation of a strategically aligned portfolio that enables optimal resource extraction is critical within identified constraints. It is therefore necessary to plan for optimal extraction of the orebody to derive both short and long term benefits. Planning is also important to ensure that operational objectives are aligned to the corporate goals of the company.

Focus on mineral resource management has become essential in order to ensure the continuous growth and profitability of a mining venture (Lerm, 2000). This means that the mineral resource manager needs to proactively and dynamically manage the resource, based on the variable nature of the internal and external environment of the industry (Lerm, 2000). Mining companies are lately experiencing pressure from stakeholders to provide security and more confidence in mine planning (Lerm, 2000). Therefore, it is important to test the performance of mine planning.

Production bonuses (productivity rewards) are often derived from production tonnage which does not take account of the fact that large tonnages of waste can be moved which brings no revenue. Rewards of this nature can be motives to deviating from mine plans, this means achieving tonnages but not according to the mine plans. Bad planning or deviating from a good mine plan could give short term benefits while destroying the long term value of the resource. Deviating from a mine plan could also compromise health and safety standards. It can be argued that tracking production against the mine plan is needed for both internal and regulatory compliance.

Compliance with leading practice mine plans is fundamental to the project management process and therefore it is important to monitor any deviation from mine plans and effectively remedy the situation if possible (Angelov & Naidoo, 2010). Leading practice mine

plans refer to high standard mine plans in terms of the orebody capability and other planning considerations such as cooperate goals. It is against these backgrounds that the concepts of 'Mine-Call-Factor' and 'reconciliation' were introduced as measurements of plan compliance. It can be argued that these measures have their own strengths and weaknesses, but there is a need to investigate how productivity can be aligned with plan compliance measures.

The ultimate purpose of mining is to make money out of the mineral resources. Therefore, mining projects are continually evaluated to ensure that they are economically feasible. Different organizations within the operation produce periodical reports to provide feedback to their stakeholders. Among others, production reports and financial statements are some of the reports made available. However, there is a need to integrate the Balance Sheet, Income Statement and Cash Flow Statement in order to make decisions in necessary areas. On this basis, financial modelling is often used to quantify potential impacts of decisions. The impact of productivity (from planning to mill) also needs to be quantified and correlated to the value added.

In order for coal to retain its status as preferred energy source, it must be delivered to the customer at the right quality and reasonable price (Angelov & Naidoo, 2010). To combat any decline in thermal coal prices, the producers must improve productivity to reduce their production costs (Angelov & Naidoo, 2010). Planning is essential in all mining operations to ensure the optimal overall extraction of reserves (Angelov & Naidoo, 2010).

Angelov and Naidoo (2010) further described three distinct levels of planning: life of mine plan, long term plan, and short term plan. Short term planning (STP) applies to a one-year period within a single business cycle and is concerned primarily with the day-to-day

scheduling of grade of ore to the plant requirements for the first 12 to 18 months of the long term plan (Angelov & Naidoo, 2010). The main objectives of short term planning are (Angelov & Naidoo, 2010):

- Grade control
- Cost control
- Equipment utilisation
- Capital productivity
- Labour productivity

Plan compliance then assesses the effectiveness of the planning and scheduling process as well as mining performance. Angelov and Naidoo (2010) defined several plan compliance metrics: spatial compliance, tonnes compliance and plan performance. These metrics need to be determined for the hard rock mines and the results should be compared with the measures of productivity. Due to availability of planning data from the mines studied, these metrics were not determined and an opportunity exists for further research. These metrics are defined as follow by Angelov and Naidoo (2010):

Spatial compliance (C1) is the actual mined area enclosed in the planned area compared to the total planned area for a given time period. Latest estimate plan (LE), which is determined one month prior to mining, is an updated version of the budget plan and incorporates the most up-to-date information for the period in question (Angelov & Naidoo, 2010).

Tonnes compliance (C2) is the quantity of platinum ore actually mined from the planned area, compared to the total quantity of ore contained in the planned area for a given period.

Plan performance (P1) is the total quantity of ore compared to the planned quantity of ore

to be mined for a given period. Different time periods need to be used to increase validity of results. This means daily, weekly, monthly as well as annual average spatial compliances are going to be calculated. Angelov and Naidoo (2010) outlined the following formulae for estimating compliance metrics:

$$Budget\ C1\ = \frac{Actual(m^2)}{Budget\ (m^2)} \times\ 100\%$$

$$Latest\ Estimate\ (LE)\ plan\ C1\ = \frac{Actual(m^2)}{LE\ (m^2)} \times\ 100\%$$

$$Budget\ C2\ = \frac{Actual(tonnes)}{Budget(tonnes)} \times\ 100\%$$

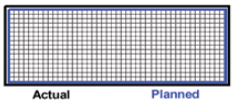
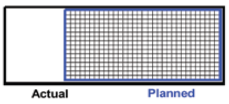
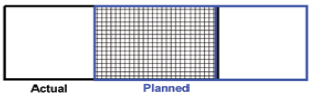
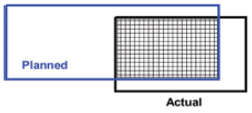
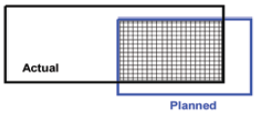
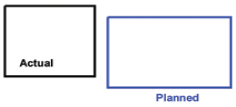
$$LE\ C2\ = \frac{Actual(tonnes)}{LE\ (tonnes)} \times 100\%$$

$$Budget\ P1\ = \frac{Actual(tonnes)}{Budget(tonnes)} \times\ 100\%$$

$$LE\ P1\ = \frac{Actual(tonnes)}{LE(tonnes)} \times\ 100\%$$

Angelov and Naidoo (2010) further investigated six possible plan compliance risk scenarios for coal mining as shown in Table 1. Although this table analyses compliance in coal mining, it forms a good basis for analysing metrics in hard rock mining.

Table 1: Coal plan compliance scenarios

Plan compliance risk scenarios					
Scenario	**C1**	**C2**	**P1**	**Coal Mining Results**	**Graphical comparison**
1	=100%	=100%	=100%	• All mining occurred from within planned mining area • All coal within the planned area was mined. • No additional coal was mined from outside the planned area • Mining did not exceed beyond the selected mining horizon	
2	=100%	=100%	>100%	• Mining included the entire planned mining area as well as outside the planned area. • All coal within the planned area was mined. • Additional coal was mined from outside the planned area	
3	<100%	<100%	=100%	• Mining included a portion of the planned area and outside the planned area. • The extent of both planned and actual areas are equal. • Volume of coal planned to be mined was equal to actual volume mined.	
4	<100%	<100%	<100%	• Mining included a portion of the planned area and/or outside the planned area. • The actual area of mining was less than the planned area. • Less coal was mined than what was planned.	
5	<100%	<100%	>100%	• Mining included a portion of the planned area and outside the planned area. • The actual area of mining was larger than the planned area • More coal was mined than what was initially planned.	
6	= 0%	= 0%	> = < 100%	• Mining did not occur within planned area. • All coal was mined from outside the planned area	

Source: Angelov & Naidoo (2010)

2.5. Contractor versus in-house mining

Contractor mining is often referred to as outsourcing, which means the transferring of responsibility for an area of service, its objectives and activities, from management to a second party (Heili, 2005). Heywood (2001) quoted by Heili (2005) defines outsourcing as "The transferring of an internal business function or functions, plus any associated assets, to an external supplier or service provider who offers a defined service for a specified period of time, at an agreed but probably qualified price." For example, in mining shaft sinking has been and continues to be outsourced, partially because of the specialized skills required. Furthermore, shaft sinking is not an on-going activity in a mining operation and retaining

equipment and employees can be financially unviable. Heili (2005) outlined the main reasons of outsourcing as:

- The desire to concentrate on core activities.
- The need to improve the service or result of the endeavour.
- The need to reduce costs.

Heili (2005) further identified the following as drivers of outsourcing: improved cash flow; the need to relocate; non-competitive systems; consolidation of the latest improvements and release of scarce resources for other areas of business. Outsourcing has several advantages including financial benefits, flexibility, efficiency and effectiveness. Anon (1997) cited by Golosinsiki (1998) stated that the Australian mining industry has recognised that outsourcing mining operations may have several benefits:

- The use of contractors facilitates elimination or reduction of inappropriate work practices and low productivity (Golosinsiki, 1998). For example, in-house drill operators would have fixed salaries irrespective of the metres drilled. However, if contractors are used, this risk is then transferred to the contractors and since their major payment is per metre drilled, the contractors will be more motivated to achieve or exceed targets.
- The contractor assumes the responsibility for industrial relations, annual leave, sick pay, pension plans and training (Golosinsiki, 1998).
- The contractor assumes responsibility for some mining-related risks such as equipment breakdown or inclement weather (Golosinsiki, 1998). However, to the owner, the cost of mining is fixed until the contractor imposes inflation and other increments.

- The contractor is more able to vary the level and composition of the workforce and to maintain the capital at optimum level (Golosinsiki, 1998). This could include practices such as low salaries for the employees and/or keeping the number of employees to a minimum. This facilitates easy adjustment of production rates over time to optimum levels (Golosinsiki, 1998).
- The use of contract mining allows the mining of deposits that are small or for which the extent and quality are uncertain (Golosinsiki, 1998). Often, it is difficult to finance such projects due to the risks involved and well established mining companies are too busy for such projects.

Although outsourcing includes transfer of risks, it also has potential disadvantages including, but not limited to:

- Unexpected costs which are not explicitly in the scope of the agreement (Heili, 2005).
- Higher per unit of service costs if usage projections are above or below those agreed upon (Heili, 2005). This means, if not well managed, outsourcing could result in lower productivity.
- Costs of additional skills and resources required in managing the relationship between contractors and the mining company (Heili, 2005). This means when the contractors experience higher input resources costs, they are most likely to superimpose these on the owner. Therefore, it is important to make sure that productivity of contractors is maintained at an optimum level to realise the value of money paid to them.

- Leakage of confidential information resulting in competitive disadvantage or legal cases (Heili, 2005). Since contractual agreements are of finite period, contractors are not bound to one company and as they move between companies (competitors) they could pass on confidential information about their rivals.
- Exposure to service provider's lack of commitment: Contractors tend to focus their attention on larger or more strategic customers (Heili, 2005). Depending on the credibility and reliability of the contractors, competition can be very high and as such high costs could be accumulated.
- Loss of in-house expertise. Relying on outsourcing makes management lose focus on the need to train and have in-house expertise (Heili, 2005). Sufficient in-house expertise is important and this is linked to the previous point where contractors could be expensive, depending on the competition. Those in-house experts would also be more familiar with production processes and day-to-day deviations from planned production.

2.6. Productivity rewards

Mining performance could be substantially improved if more managerial knowledge were employed in enacting the strategies to exploit the mineral resource (Camus, 2002). Managerial work includes giving extrinsic motivation to the employees to improve their labour productivity and thereby improve overall mine productivity. Work by Frederic W. Taylor (1911) in the United States and Henri Fayol (1916) in France concentrated on management problems and theories (Camus, 2002). Both identified productivity problems and personnel management as keys to industrial success and applied rigorous analysis to

solve the two problems (Camus, 2002). Industrial success is easily achieved by taking care of human factors as much as possible.

There are several schools of thought when it comes to describing discussed human behaviour in the work place in detail. From the perspective of the human relation school, the individual is seen as an agent with feelings and self-interested goals that often conflict with organisational goals (Camus, 2002). Therefore, insights about working conditions and the informal aspects of the organisational structure are often seen as additional factors to consider when shaping managerial policies (Camus, 2002). Linked to this is the effect of salaries and bonuses. Consequently, in this study the ratio between the salaries of in-house employees and contracted employees will be determined as well as the ratio between their salaries and bonuses.

According to Bates (1982), incentive bonuses played an important role in the mine production at Magmont. Magmont mine produces lead using trackless, room and pillar mining method, making this mine comparable to platinum mines because they also use the same mining method. These bonuses were paid on a per foot basis and they increased exponentially as output increased (Bates, 1982). Although incentive bonuses increased with increased output, health and safety was not compromised. Apart from safety training of new employees at Magmont, the safety programme was supported by all levels of management and as a result Magmont was awarded a trophy by the Mine Safety and Health Administration in 1976 and 1979 (Bates, 1982). It is clear that it is important to investigate the correlation between the safety performance of mines and various measures of productivity. Ultimately, incentive bonuses should cater for health and safety as well as productivity to maintain the mine's social license.

2.6. Conclusion

This Chapter has highlighted the different measures of productivity which can be calculated and applied in decision making. The challenges faced when calculating these measures were also highlighted in the Chapter. However, the squeeze in profit margins combined with other factors such as labour unrest, call for constant attention to production efficiency. It is also important to measure and analyse productivity trends within the company and/or across the mining sector. Given the unique nature of mining projects, a fair comparison would require selection of projects which are fairly similar based on some sort of criteria. Therefore, Chapter 3 will discuss the process followed in the selection of data used in this report.

CHAPTER 3: OPTIMAL EXTRACTION AT AMPLAT MECHANISED MINES

This Chapter is aimed at finding ways of analysing the measures of productivity and productivity rewards at selected mechanised South African platinum mines. The Chapter outlines and describes the process followed in obtaining data and using insights from literature to analyse data. It includes questions asked, observations made and a record of what is contained in literature. The Chapter will start with a brief background into productivity as a measure of performance, source(s) of data as well as research questions to be considered.

3.1. Background

Accessibility and drop in grade of PGM reserves in the BIC necessitate optimal extraction, which includes effective application of input resources to extract minerals at a profit. On this basis, companies measure and reward productivity as a measure of some degree of production efficiency. Musingwini (2009) stated that, optimal extraction of ore requires that a maximum amount of ore be extracted by hauling a minimum amount of waste in the shortest possible time, at the lowest cost in a safe and most environmentally acceptable manner.

Optimal resource extraction is often thought of in terms of alignment of the operational plan to the strategic plan of the company. There is a need for a good leverage in planning considering the current business environment, including the risk of nationalisation and operational threats such as labour unrest. On this basis, in the context of this report, optimal resource extraction is rather the ability to leverage well between the strategic plan, operation and the principal asset's ability. Without underestimating other assets, the

principal asset refers to the orebody and its ability depends on it availability and utilisation among other factors.

Traditionally, narrow tabular orebodies, mainly gold and platinum, have been mined by a conventional mining method. This method requires the use of jackhammers for drilling and scraper winches to clean the blasted material. While this method gave good head grade because of lower amounts of dilution, the method is labour intensive. In an effort to increase productivity, the trackless, mechanised mining method was adopted by some mines.

It has been previously stated that mining is a profit-driven business with an ultimate aim of growing the investor's wealth while assisting the host government in supplying and sustaining jobs. As such, mines and mining companies aim to compete with local and global practices hence, the concept of benchmarking. According to Kemp (2000)**,** benchmarking is a very useful tool used for measuring a company's performance and practices versus "best-in-class" companies. Examples of such measurements and comparisons include industry cost curves which will be briefly mentioned in this report. Kemp (2000) further described benchmarking as "a process of finding the world-class examples of a product, service or operational system and adjusting your products, service or systems to meet or beat that standard."

The best-in-class companies can be direct competitors, that are companies exploiting the same commodity, and these companies could be domestic or foreign. However, platinum mines are not necessarily in competition with one another as physical platinum output is generic in nature and unbranded. Thus, in the platinum industry, benchmarking should

provide a guideline for the industry and investor as to which operations are the “best” in different key performance areas.

Cost curves are just one set among many measures of performance. Performance is described as the translation of actions or input resources into an actual outcome or tangible end (Harbour, 2009). Coelli, Prasada Rao, O’Donnell and Battese (2005) stated that the performance of any factory/firm can be defined in many ways because firm owners and/or managers use several inputs to achieve some set of outputs. Coelli et al (2005) further believed that the natural measure of performance is a productivity ratio. As defined in previous Chapter(s), this is the ratio of outputs to inputs.

Depending on the ratio calculated, often larger values of this ratio are associated with better performance. For example, a larger value for revenue per capital invested, reflects good performance. However, for cost per operating employee a smaller value will show good performance. Performance is often done comparatively. For example, the performance of a company/firm in 2012 could be measured and compared to its 2011 performance or it could be measured relative to the performance of another company/firm in 2012 and so on. Often, measures of performance are reported in silos. It is therefore important to establish any existing relationship among performance measures to understand the complete mining business.

3.2. Source(s) of data

Data was obtained from Anglo American Platinum (Amplat) annual reports. The selection of Amplat was for the completeness of their reports in the public domain, hence ease of access to data. Moreover, a similar study was done for the gold mining industry by Clatworthy (1994). Amplat owns and/or has shares in a number of mines which are all different in terms

of the mining methods used, grade mined as well as composition of ownership. To this effect, three mines (Bathopele, Kroondal and Mototolo) were compared. Although it is appreciated that no two mining projects can be exactly the same, the three mines were considered to be fairly similar because they are all mechanised, they all mine the Upper Group 2 (UG2) reef and they are all fairly shallow. Shallow in this context refers to any depth shallower than 500m.

These mines were compared to determine the effect of employment practices on mines being 100% owned by a single company and mines co-owned by at least two mining companies. Labour costs make up at least 50% of the mining costs in most mines. As a consequence labour issues are becoming critical in the mining industry and continue to squeeze the profit margin. To this effect, although salaries are not publicly reported, data for this project was obtained with the help of the project co-supervisor as indicated in acknowledgements.

3.3. Assumptions

Due to limited scope as well as confidentiality of some information required for this project such as salaries, some assumptions were made. The author assumed that:

- All labour hours and conditions were identical and additive.
- The average platinum price and/or exchange rate was a true reflection of what had happened throughout the month/year unless there were anomalies causing concern.
- Terms of agreement between contractors and owners were standard and did not impact productivity.

3.4. Research question(s)

In order to provide the necessary focus to the study, the following questions were formulated to aid in understanding productivity at selected mines:

1. What are the current measures of productivity reported and how is productivity understood and rewarded by Amplat?
2. What are the major limiting factors in rewarding productivity?
3. What are the productivity trends at the three mines selected?
4. Can productivity be linked to employment practices?
5. What are the fundamental causes of productivity trends?
6. How do measures of productivity relate to accounting/economic performance?
7. What are the productivity drivers between short term planning and the concentrator?
8. What are the possible ways of benchmarking and possibly rewarding productivity?
9. What is (has been) the ratio between the bonus and basic salary and what are the possible implications of this ratio?
10. While productivity might seem to increase when commodity prices are high and/or coupled with a higher exchange rate, can this apparent productivity increase be tested with real data?
11. How does productivity relate to plan compliance measures/metrics?

3.5. Conclusion

Chapter 3 classified Bathopele, Kroondal and Mototolo to be comparable because they are all shallow, they are all mechanised and they are all currently mining UG2. Because of their full or partial ownership by Amplat, these mines also report productivity in a similar way and are expected to be comparable seeing that they all need to meet the Amplat strategic plan. On these bases, Chapter 4 discusses the trends in production and productivity among the three mines. Calculations and graphs in Chapter 4 are mainly based on Amplat annual report, extracts from this report are shown in Appendix A.

CHAPTER 4: PRODUCTIVITY TRENDS AT SELECTED AMPLAT MINES

Productivity is a measure of production efficiency and it is therefore important to discuss productivity hand-in-hand with production. Therefore, this Chapter will start by providing a comparison of production trends between the three mines, Bathopele, Kroondal and Mototolo. The Chapter will first establish how in-house mining and contractor mining compare in terms of volumetric and/or size measures. The Chapter aims to answer research questions 1 to 6 in section 3.4.

This Chapter further aims at understanding the measures of productivity reported by Amplat between 2007 and 2011, both years included. The Chapter explained trends and differences in trends between the three mines under study, thereby aiding in explanation of the impacts of in-house compared to contractor mining. The Chapter further evaluates any relationship between measures of productivity. This Chapter compares trends in productivity and the meanings of measures reported, while looking at the drivers of these measures as well as highlighting the barriers to productivity.

Amplat reported two labour-based and three financial-based measures of productivity. The labour-based were:

- Square metres per total employee.
- Refined platinum ounce per total operating employee.

The financial measures of productivity were:

- Cash-on-mine costs per tonne milled.
- Cash operating costs per equivalent refined ounce of platinum.
- Cash operating costs per refined ounce of platinum.

These different measures of productivity are explored further in this Chapter.

4.1. Production data

4.1.1. Tonnage

Kemp (2000) stated that production data often relates to volume, quality and ore resource management. The common production parameters used generally include metres advanced, square metres mined, tonnages of rock moved or milled and so on. Kemp (2000) also indicated that during his study sometimes important factors used in analysis of production are not readily available in the public domain. These factors include mine call factor, block factor, as well as sweeping and tramming widths (Kemp, 2000).

At Kroondal, broken ore is sent to the Dense Medium Separator (DMS), from which the concentrate is sent further for milling and discards to the tailings. Ore transportation inefficiencies will always cause a difference between tonnes broken and tonnes milled, but pre-concentration caused a difference as high as 39%. At Bathopele and Mototolo, broken ore is sent directly to the mill as there is no DMS. This caused the average variances between tonnes broken and tonnes milled at Bathopele and Mototolo to be 7% and 4% respectively. For this report tonnes broken were used to eliminate the effect of pre-concentrating which is done at Kroondal. Figure 3 shows the annual tonnes broken for the three mines under study.

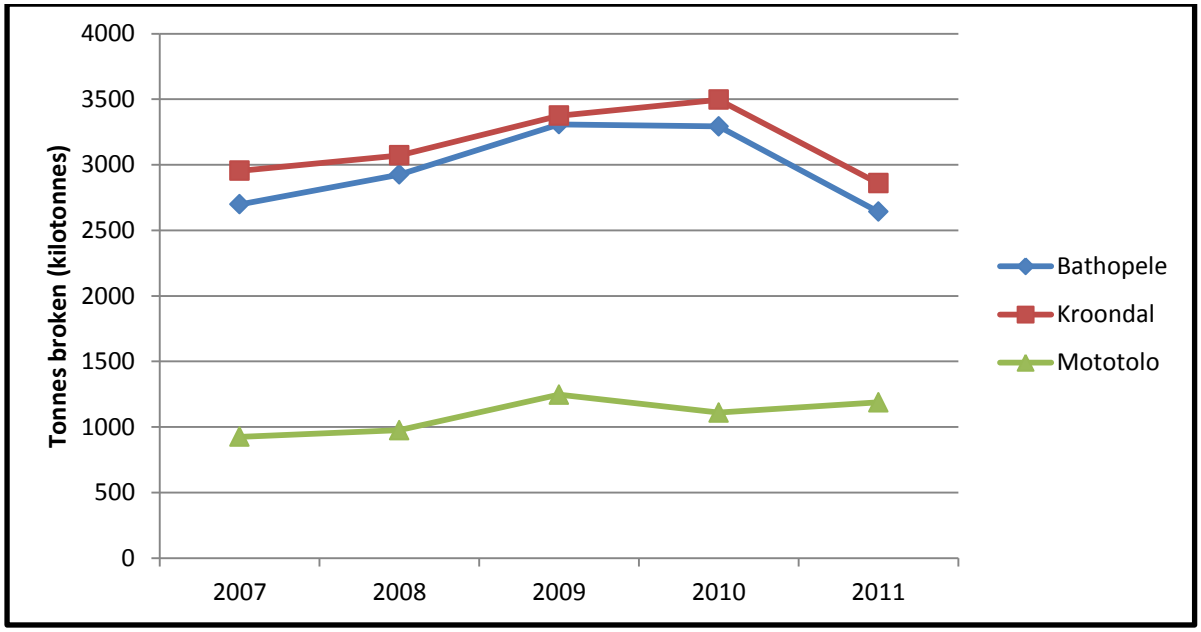


Figure 3: Tonnages broken 2007 – 2011 (Anglo American Platinum Limited, 2011)

On average, as shown by Figure 3, Bathopele annual production was about 63% higher than that of Mototolo, but about 6% lower than that of Kroondal. While Bathopele current maximum operating depth (300m) is shallower than that of Kroondal (450m), the quantity of ore broken at Bathopele was 6% lower than that of Kroondal. There is a relatively small difference between tonnes broken at Bathopele and Kroondal. This small difference can be attributed to the similarities in the designed capacity and mining conditions among other factors between the two mines.

The difference shown in Figure 3 exists because there are always differences in mining projects. Tonnage is a product of square metres mined, stoping width and density. Mototolo is completely different by geology and rock density compared to the other two mines. The difference in tonnes broken between the Bathopele and Kroondal can be attributed mainly to the difference in stoping widths.

Figure 3 shows a steep decline in ore broken at both Bathopele and Kroondal from 2010 to 2011. This trend could be linked to labour disputes during this period. Kemp (2000) described tonnes broken as an indication of the size of a mine. The size of the mining operation here refers to the designed capacity of the mine and the number of employees. Therefore, Figure 3 could highlight the difference in size of mining operations between the three mines. However, the difference in tonnes broken can also be attributed to the differences in: stoping width, number of operating shafts, as well as the capacity of the ore treatment facility. For example, Kroondal has four shafts compared with two at Mototolo.

While these three mines are comparable as they are all fully mechanised, it was noted that the production and productivity reported for the joint ventures is only that part attributable to Anglo American Platinum. Therefore, while these values give an indication of how well Anglo American Platinum is doing, they are not a full reflection of how these mines are doing overall. Taking all of the above into account this means that only Bathopele production figures are complete, because it is 100% Anglo American Platinum owned and all production is attributed to Anglo American Platinum.

4.1.2. Area mined

The above argument (ownership effect on production data reported) forms a basis for another comparison between the three mines which aims to eliminate ownership effects. Figure 4 shows the average annual square metres mined at these mines.

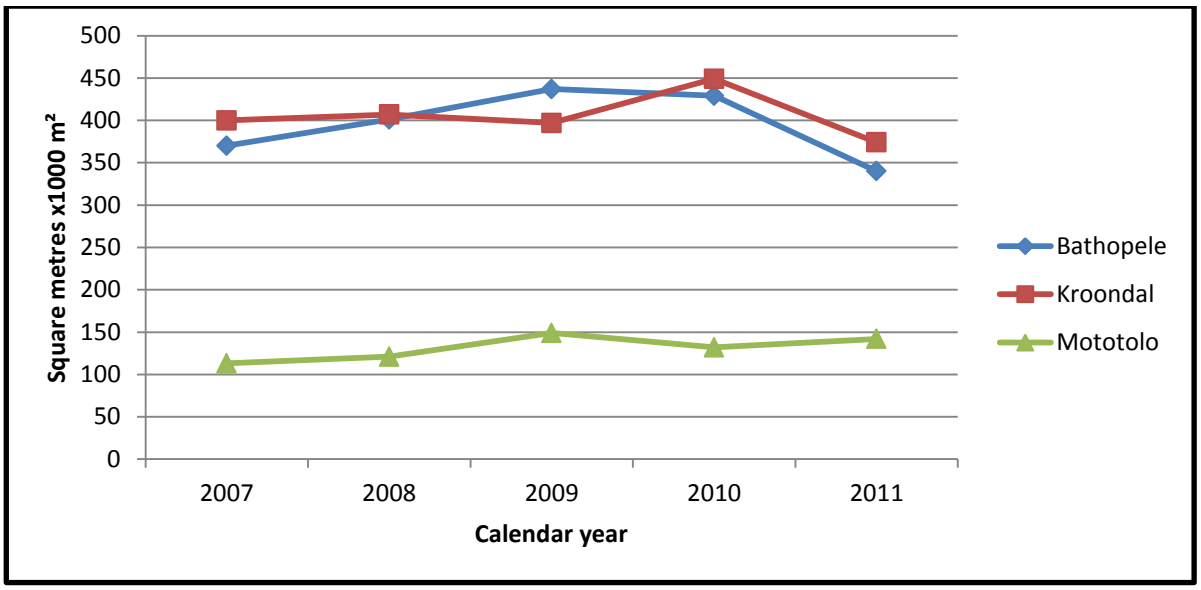


Figure 4: Square metres mined 2007 - 2011 (Anglo American Platinum Limited, 2011)

Again, Kemp (2000) describes this parameter as an indication of size paired with degree of flexibility, geographical spread and exposure to disasters which may affect production. The differences in: mining conditions, sizes of mines and orebodies mined by the three mines are again evident from Figure 4 where line graphs of Bathopele and Kroondal are closer to each other and higher than Mototolo. The role of stoping width is also evident in Figures 3 and 4. In Figure 4, the gap in square metres mined by Bathopele and Kroondal is narrower than that in Figure 3.

The average difference in square metres mined has been consistently high between Bathopele and Mototolo as well as between Kroondal and Mototolo. This means, the area mined is not highly dependent on whether it is in-house or contractor mining but rather on the degree of flexibility of the mining area. Bathopele and Kroondal are in the western limb of the BIC and therefore experience similar geological disturbances.

On the contrary, Mototolo experiences severe challenges because of large areas which are often abandoned at one of its shafts due to oxidised rock strata. This, coupled with other

challenges reduce the degree of flexibility at Mototolo and the area mined thereof. While reporting area mined is still useful, its high dependence on geology among other factors calls for other measures to be reported. Thus, the next section discusses the trends in refined platinum.

4.1.3. Refined platinum

Both tonnes broken and squares mined, emphasise the effect of stoping width, but do not address other operational variables such as metal ratios and plant recovery percentages. This is because the square metres mined are not a direct reflection of the final product(s) refined because of differences in grade, dilution, and mine call factor among other factors. This necessitated another basis for comparison and Amplat reports on refined platinum production were used in Figure 5 which compares Bathopele, Kroondal and Mototolo in terms of refined platinum produced to investigate the impact of grades among other issues across the mines.

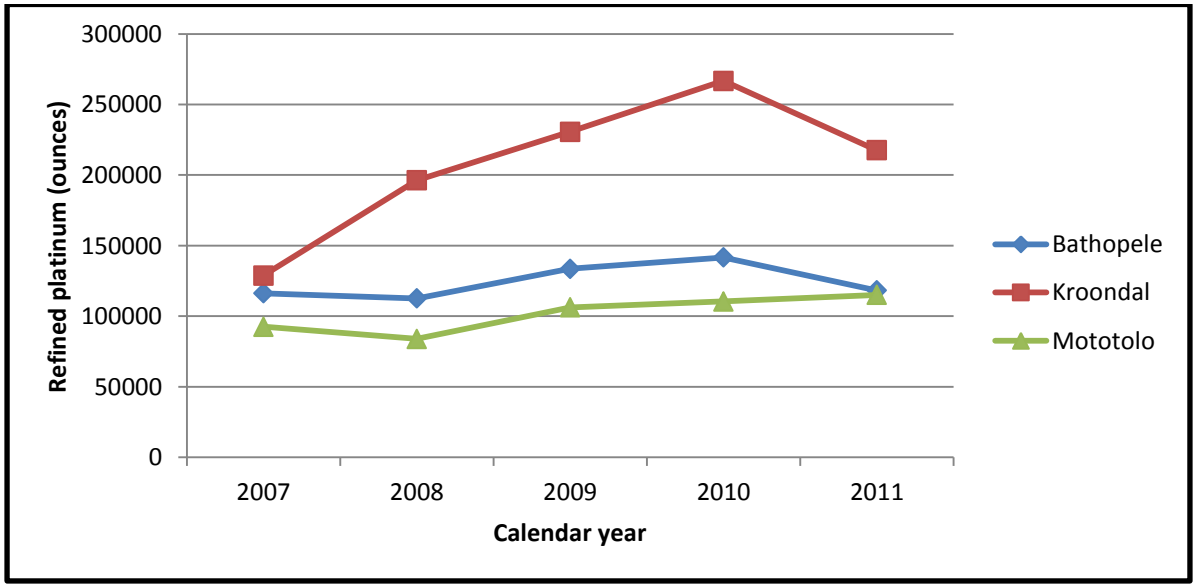


Figure 5: Refined Platinum 2007-2011 (Anglo American Platinum Limited, 2011)

In line with the labour disputes experienced in 2011 at Bathopele, refined platinum decreased steeply by 17% between 2010 and 2011. Overall Kroondal produced more refined platinum than Bathopele and Mototolo. Figure 5 shows the amount of refined platinum at Kroondal steeply increased from 2007 to 2010 and then decreased by about 18% from 2010 to 2011. Mototolo showed a flat, consistent trend except in 2008 and 2009 where the quantity of refined platinum changed by -9% and 27% respectively from previous years. Table 2 below shows all year-on-year variances in refined platinum. The Table quantifies and summarises the year-on-year changes from Figure 5.

Table 2: Year-on-year variances in refined platinum

Year	Variance (%)		
	Bathopele	Kroondal	Mototolo
2007-2008	-3.2%	52.4%	-9.4%
2008-2009	18.7%	17.5%	26.7%
2009-2010	6.0%	15.6%	4.0%
2010-2011	-16.5%	-18.4%	4.2%

Source: (Anglo American Platinum Limited, 2011)

From Figure 5 and Table 2 it can be seen that there were some steep increases in refined platinum at all three mines. This increase can be attributed to improved labour efficiency, better fleet management, increase in 4E[1] head grade and increase in tonnes milled (Anglo American Platinum Limited, 2009). Refined platinum is a product of tonnage, grade as well as recovery factors in the concentrator and in the refining smelter. Therefore, the trends

[1] 4E grade mainly includes **platinum, palladium, rhodium, gold** and some traces of ruthenium, osmium, iridium, nickel, copper and cobalt.

(positive and negative peaks) mentioned above can also be attributed to variations in grade, metal ratio as well as recovery factors in the concentrators and smelters.

Figure 6 shows the trends in the 4E built up head grade (in grams per tonne milled) for the three mines studied. The head grade is further affected by the metal ratio, which is indicative of what percentage platinum is contained in the concentrate. For example, in 2010 platinum constituted about 55% and 61% of the UG2 reef at Bathopele and Kroondal respectively (Anglo American Platinum Limited, 2011). This further emphasises the higher refined platinum produced at Kroondal.

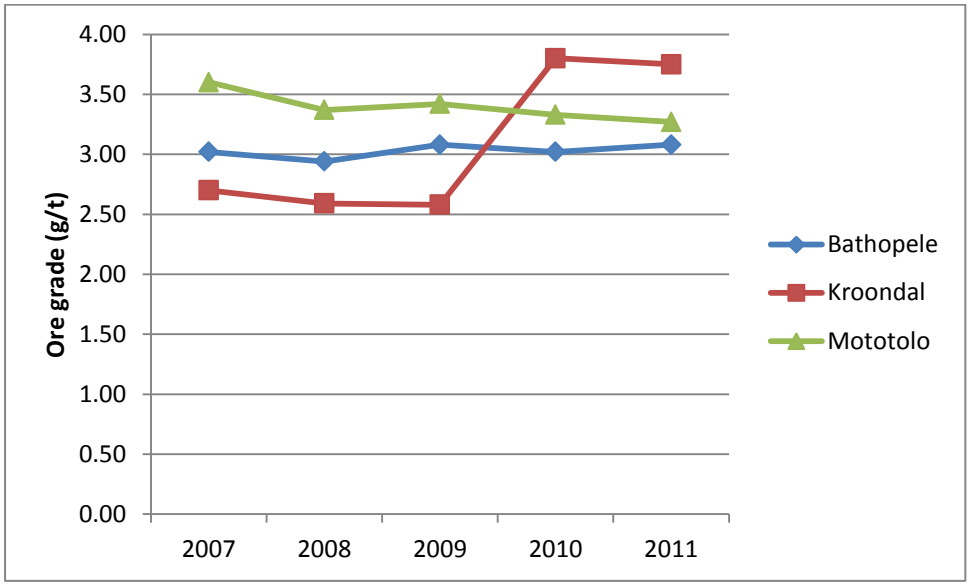


Figure 6: Ore grade 2007-2011 (Anglo American Platinum Limited, 2011)

Figure 6 does not show similar trends to those in Figure 5. Therefore, the differences in refined platinum among the three mines as well as the year on year variances within the same mine can be attributed to these metal ratios in milled tonnages in addition or in isolation to processing efficiency. While Bathopele and Mototolo showed flat trends in grades, Kroondal showed a steep increase in grade in 2010 (up 47% from 2009). This increase in grade can be attributed to improved efficiency in the DMS which was sustained

in 2011, perhaps a technological advancement/refurbishment of the DMS. Table 3 shows the year on year variances in grade.

Table 3: Year on year variances in grade

Year	Variance (%)		
	Bathopele	Kroondal	Mototolo
2007-2008	-2.6%	-4.1%	-6.4%
2008-2009	4.8%	-0.4%	1.5%
2009-2010	-1.9%	47.3%	-2.6%
2010-2011	2.0%	-1.3%	-1.8%

Source: (Anglo American Platinum Limited, 2011)

Refined platinum reported in Anglo American Platinum annual reports is that attributable to Amplat. While trends in some production parameters matched, it is important to establish and quantify any relationship between production data. Therefore, Table 4 shows the correlation coefficients between production parameters.

Table 4: Correlation between variables

	Correlation coefficient:		
	Square metres mined and tonnes broken	Square metres mined and refined platinum	Tonnes broken and refined platinum
Bathopele	0.97	0.90	0.97
Kroondal	0.78	0.43	0.70
Mototolo	1.00	0.81	0.86

Source: (Anglo American Platinum Limited, 2011)

In the context of this report, the strength of the correlation coefficient, r is defined as follow (StatPrimer, n.d):

$0 < |r| < 0.3$ weak

$0.3 < |r| < 0.7$ Moderate

$0.7 < |r| \leq 1.0$ Strong

Based on the above defined ranges, Bathopele and Mototolo show very strong linear relationships between all the three production measures. This means, any of the three production measures at these two mines can be used to predict the other quite comfortably. Furthermore, improvement in processes affecting one parameter would improve the other parameters almost linearly.

Kroondal showed strong correlations between square metres mined and tonnes broken as well as tonnes broken and refined platinum, but a moderate correlation between square metres mined and refined platinum. These correlations at Kroondal coupled with the higher amount of refined platinum produced further emphasise the size of Kroondal in terms of stoping width, high content of platinum in the head grade and processing efficiencies.

4.2. Current Amplat measures of productivity

4.2.1. Square metres per total operating employee

Kemp (2000) considers this to be a fair comparison between mines as long as it is narrow ore bodies that are compared with each other. Therefore, this measure is highly valid in the context of this project because the mines compared are all mining low profile UG2. Figure 7

shows the trend in square metres per operating employee per month between 2007 and 2011.

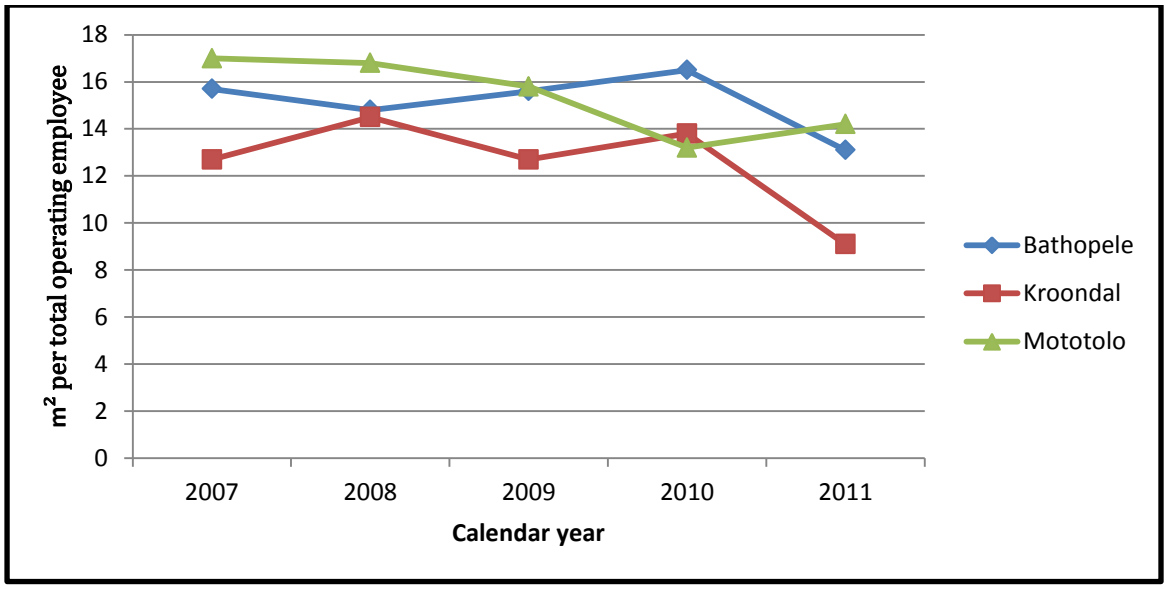


Figure 7: Square metres per total operating employee (Anglo American Platinum Limited, 2011)

Mototolo showed a steady decrease in productivity between 2007 and 2010. This trend can be attributed to failure to offset the increase in number of employees with an increase in square metres mined. The increase in square metres mined was steady, most probably because the geological conditions at Borwa shaft interrupted production frequently, reducing the availability of the working faces at Mototolo. Figure 8 shows the average number of employees employed by the different mines between 2007 and 2011.

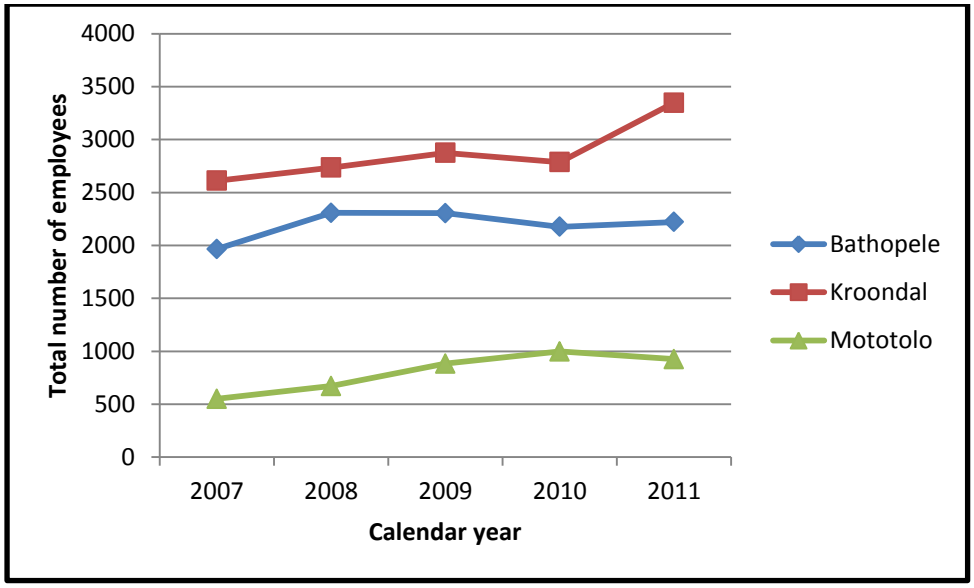


Figure 8: Average number of employees (Anglo American Platinum Limited, 2011)

Bathopele and Kroondal showed similar trends in square metres mined per operating employee (Figure 7) which are in line with their similar trends in square metres mined (Figure 4) and also in line with their similar number of employees (Figure 8). Square metres mined per operating employee steeply declined in 2011 at Bathopele and Kroondal because during the same year, the number of employees increased at both mines while square metres mined, decreased due to labour disputes.

Figures, 4, 7 and 8 showed that the relationship between square metres mined per operating employee and the number of employees is not a simple inverse proportion nor is there a direct proportion between the square metres mined and this measure of productivity. This means, external factors affecting productivity are mine unique and as such decisions based on measures of productivity cannot be generalised across mines unless a benchmark is established. Table 5 shows the changes in number of employees, square metres mined as well as in the square metres per employee.

Table 5: Variation in several measures between years

	Year on year percentage change in:								
	Square metres mined			**Number of employees**			**Square metres per employee**		
	Bathopele	***Kroondal***	***Mototolo***	***Bathopele***	***Kroondal***	***Mototolo***	***Bathopele***	***Kroondal***	***Mototolo***
2007-2008	8.38	1.75	7.08	17.34	4.71	21.96	-5.73	14.17	-1.18
2008-2009	8.98	-2.46	23.14	-0.09	5.12	31.4	5.41	-12.41	-5.95
2009-2010	-1.83	13.10	-11.41	-5.60	-3.06	13.02	5.77	8.66	-16.46
2010-2011	-20.75	-16.70	7.58	2.07	20.09	-7.21	-20.61	-34.06	7.58

Table 5 shows that if the percentage increase in the number of employees exceeds the increase in the square metres mined, the overall square metres per employee will decrease. On the contrary, if both, the square metres mined and the number of employees decrease, there is a possibility of an increment in the square metres per employee provided that the absolute percentage decrease in the number of employees exceeds that of the square metres mined.

The stoping width is normally determined as part of the mine design process in accordance with tolerable dilution, and mining method. This means, the square metres mined in a stope are a function of machine availability and/or utilisation as well as human factors among others. Human factors can influence the number of square metres mined 'positively' or 'negatively'. Therefore, it is important to consider the factors which motivate stoping employees and minimise the negative human factors without compromising health and safety standards. These factors are discussed in section 4.2.6.

While square metres mined per employee is a fairly good measure of productivity because it is a reflection of what is happening at the stope face, it is important to also consider measures which directly link with the addition of value. All mines considered, produced platinum as their primary commodity with several by-products. As a result, another measure of productivity reported, is refined platinum per employee which is discussed in the next section.

4.2.2. Refined Pt oz per total operating employee

Unlike the square metres per total operating employee, this measure takes cognisance of value and is a meaningful indicator when ore grades are similar. Refined platinum is the final product at the mine and the quantity of this product is affected by various factors along the mining value chain of processes. Among others, accuracy of drilling and blasting, precision of short term planning input factors, grade control, quantification and minimisation of mining losses from the resource to the final product. Figure 9 shows a comparison of refined platinum per total operating employee. The line graphs for Kroondal and Mototolo are inclusive of mined and purchased refined platinum.

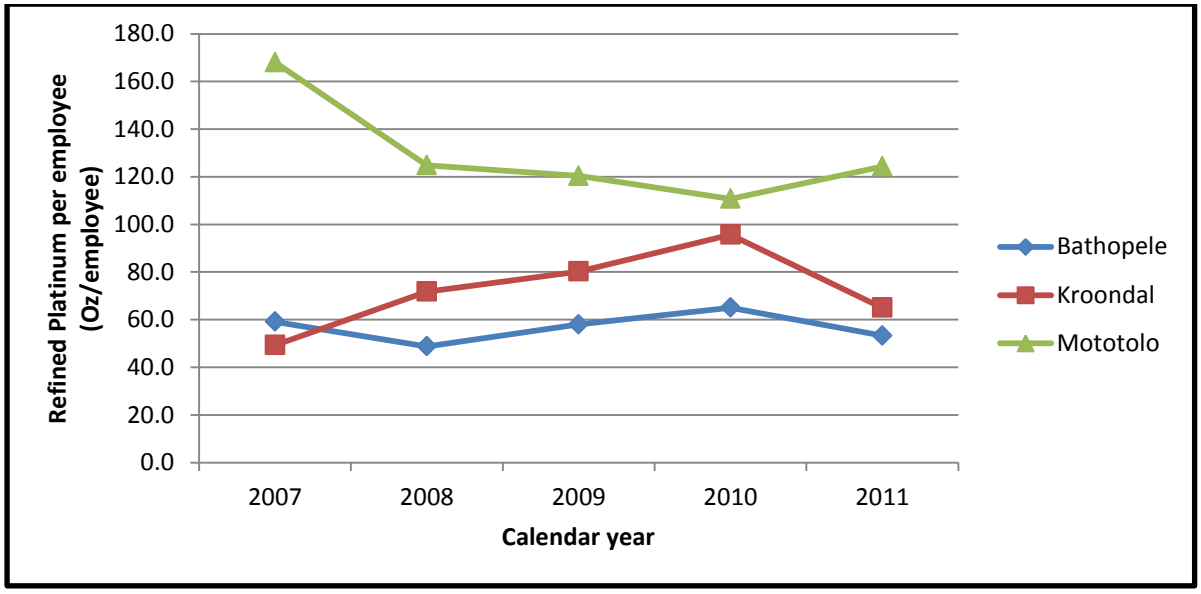


Figure 9: Refined platinum per employee 2007-2011 (Anglo American Platinum Limited, 2011)

Refined platinum per employee decreased 17% from 59.2 ounces per employee in 2007 to 48.8 ounces per employee in 2008 at Bathopele. This drop was mainly due to lower refined platinum output which resulted from closure of the Turffontein shaft, safety stoppages, Eskom power supply disruptions and contractor strike interruptions coupled with a 17%

increase in the number of employees. This measure of productivity then improved between 2008 and 2010, before decreasing again in 2011 due to safety stoppages and industrial actions (Anglo American Platinum Limited, 2011).

At Kroondal, refined platinum per employee increased between 2007 and 2010 before decreasing steeply in 2011 due to installation of a new support system (Anglo American Platinum Limited, 2011). At Mototolo, the refined platinum per employee declined from 2007 until 2010. This decline can be attributed to the increasing number of employees coupled with lower refined platinum output. This measure of productivity then improved in 2011 due to increased throughput and a 7% decrease in number of employees.

There are three major inputs to mining, namely labour, material and money. Since mining is a profit (profit = revenue – total costs) driven business, operating costs are a major concern in the mining industry. Therefore, another commonly reported measure of productivity is unit cost. This measure is widely used for benchmarking mines within the industry as well as benchmarking new projects. The next sections discuss the trend in financial based measures of productivity.

4.2.3. Unit cash-on-mine costs

Cash costs are commonly used to benchmark new or existing projects on unit cost curves. In the context of this report, cash costs refer to mining and milling cost. Cost curves are normally used together with commodity prices in order to estimate the profit margin. While companies are currently aiming to be low cost producers, there are certain factors which could assist companies in doing this. For example, instead of focusing on ways to cut costs, the focus should be on improving throughput by addressing some human factors. Figure 10 shows the unit cash-on-mine cost per tonne milled between 2007 and 2011.

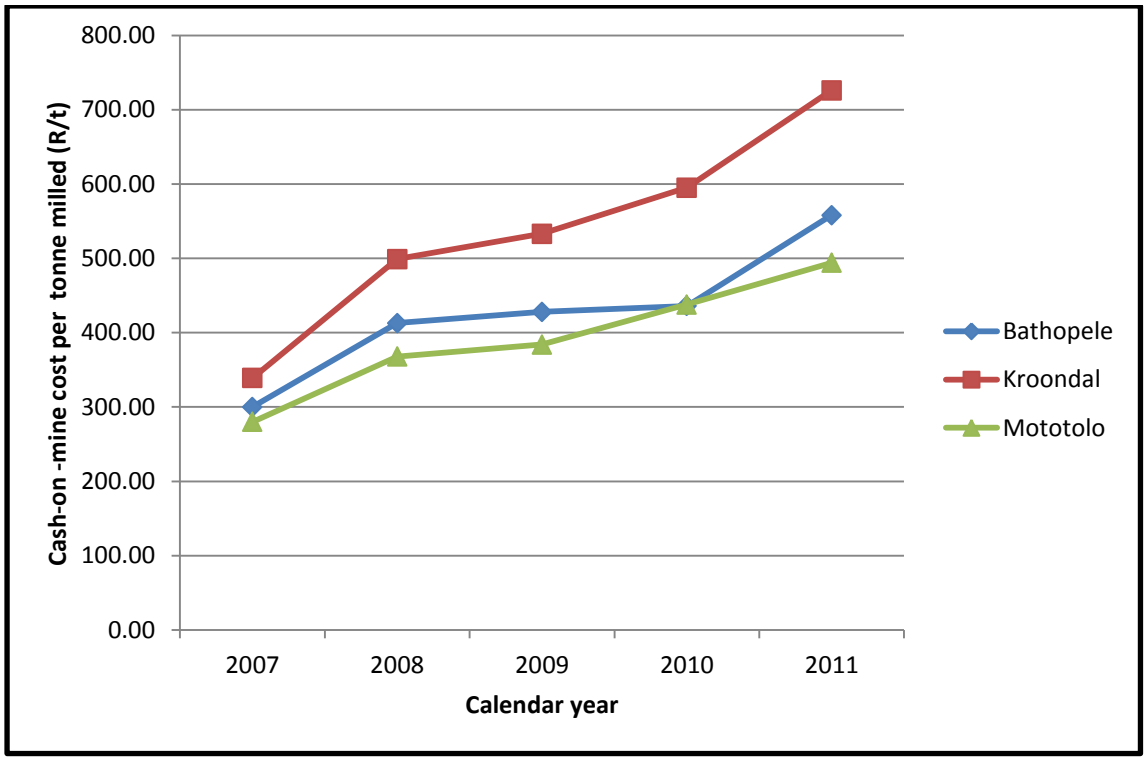


Figure 10: Cash-on-mine costs per tonne milled 2007-2011 (Anglo American Platinum Limited, 2011)

Cash on-mine costs per tonne milled, increased for all three mines. Although the tonnes milled at Kroondal fluctuated and neither showed a steady increase nor a decrease, the cash on mine costs increased. Factors contributing to increase in costs include mining efficiencies such as powder factor, advance rate, fragmentation, ore/waste handling. Moreover, variable cost elements such as metres drilled, production rates also influence overall costs. Human factors such as strikes as well as labour inefficiency also increase the overall total costs and unit costs. Figure 10 showed Kroondal to have higher unit costs than Bathopele and Mototolo because of lower volumes milled due to the pre-processing at Kroondal. Therefore, Figure 11 shows cash-on-mine cost per tonne broken to eliminate the effect of processing and spillages (transportation/ore hoisting inefficiencies).

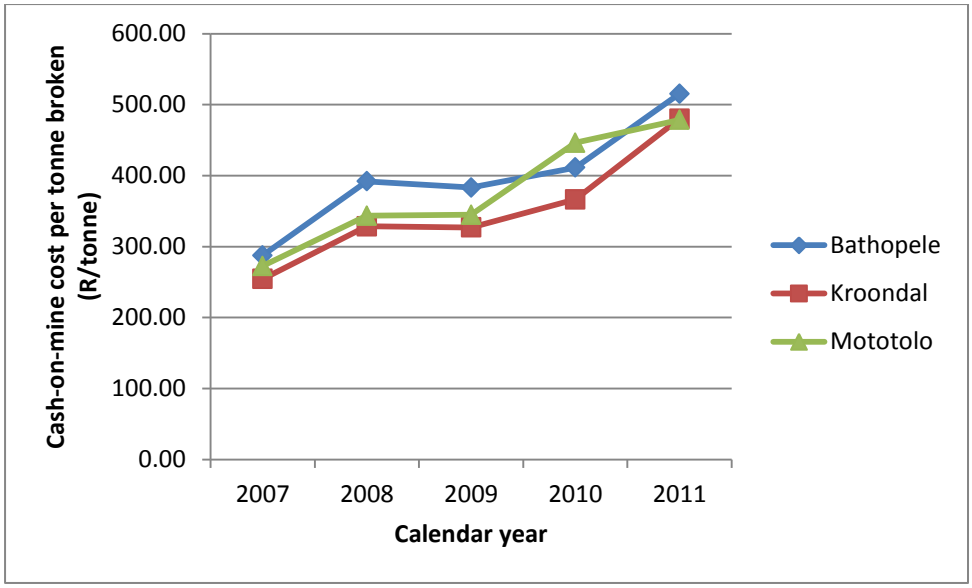


Figure 11: Cash-on-mine cost per tonne broken (Anglo American Platinum Limited, 2011)

The cash-on-mine cost per tonne broken, increased significantly in 2008 at all mines partly due to the economic crisis experienced in 2008. In line with the decrease in tonnes broken at Bathopele and Kroondal in 2011, cash-on-mine cost per tonne broken increased. Both Figure 12 and Figure 13 show that similar trends are visible for operating costs per equivalent refined platinum as well as operating costs per refined platinum. These Figures (11, 12, 13) highlight the escalation of unit costs at all three mines. This escalation is concerning and perhaps can be attributed to increase in fixed cost such as electricity and labour. Increments in salaries at Bathopele are discussed in Chapter 5.

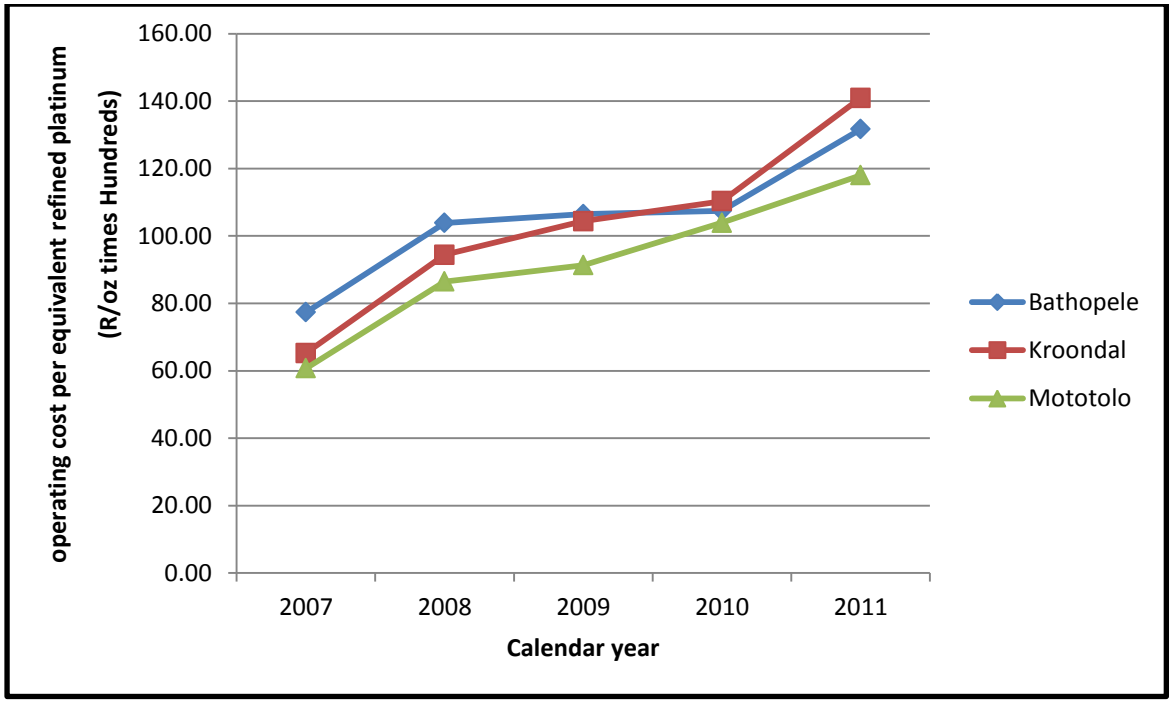


Figure 12: Cash operating costs per equivalent platinum ounce (Anglo American Platinum Limited, 2011)

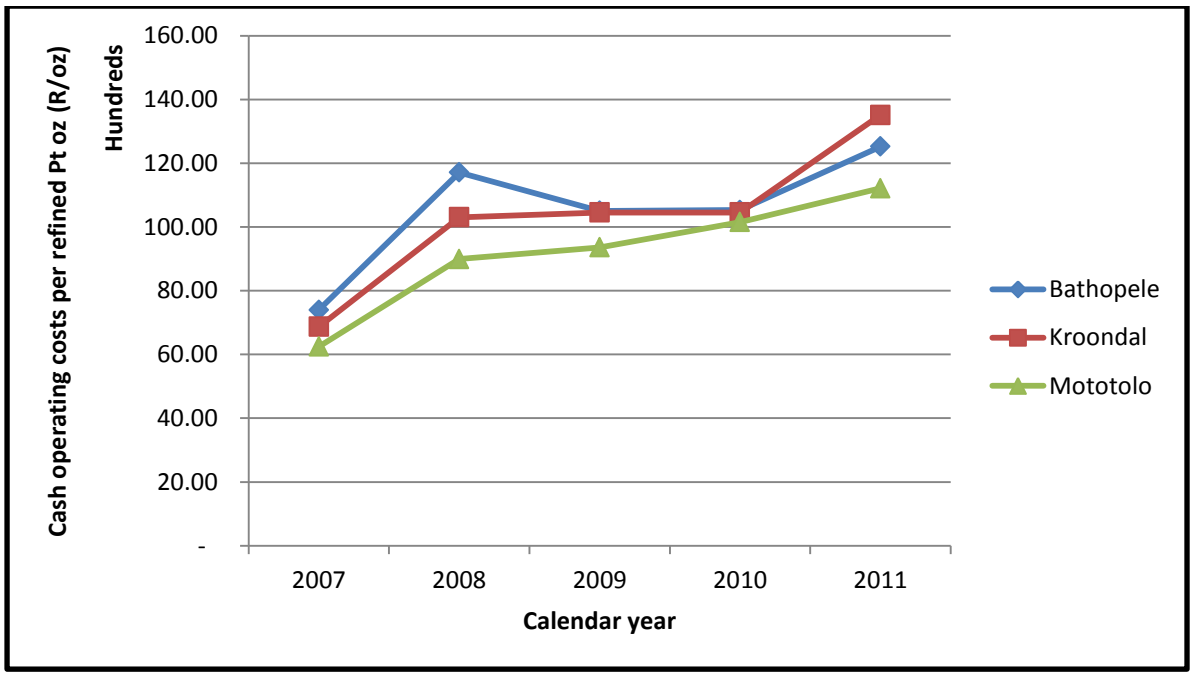


Figure 13: Cash operating cost per refined platinum ounce (Anglo American Platinum Limited, 2011)

Highest increase in cash operating cost per refined platinum as well as per Equivalent ounces of platinum are mined ounces expressed as refined ounces. Most platinum mines report unit costs per ounce of platinum. However, most of these mines have numerous by-products, therefore cannot really be judged on fluctuation of platinum prices only. The mines in the highest range of unit cost may remain in business due to revenue generated from by-products.

Generally, there are a number of factors affecting and influencing operating costs and production rate of mining companies, such as: mining method, infrastructure, equipment, geology, labour, environmental, technological and metallurgical factors. Thus, a wide range of unit costs among different mines as exemplified in Figure 14. Cost curves for years 2007 to 2010 are shown in appendix B.

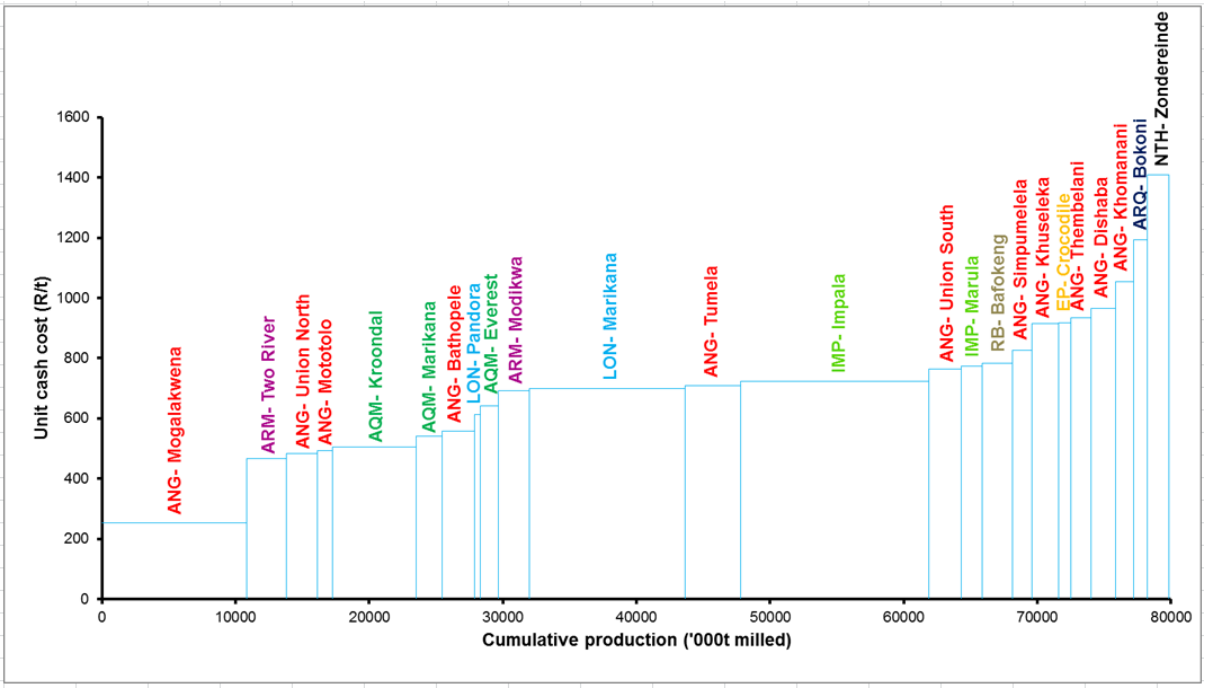


Figure 14: Platinum cost curve 2011 (Tholana, unpublished MSc thesis 2012)

While Figure 14 forms a good benchmark especially in establishing which shafts should be closed, in most companies labour constitutes up to 60% of operating costs. This calls for effective utilisation of labour as well as measurement of labour efficiency and efficiency-based incentives, thus a need to determine a measure of productivity which takes account of labour utilisation.

4.2.4. Economic performance (profitability)

While all other measures of productivity are indicative to the shareholders of how some major input resources are used, operating margins are also reported. An operating margin provides the level of profitability per mine as it measures the amount of revenue left after all sales costs. Operating margin can also be seen as a measure of operating efficiency. While common accounting ratios could not be quantified at mine levels, this was used as a financial ratio at the mine level. Figure 15 shows the trends in operating margins for the three mines.

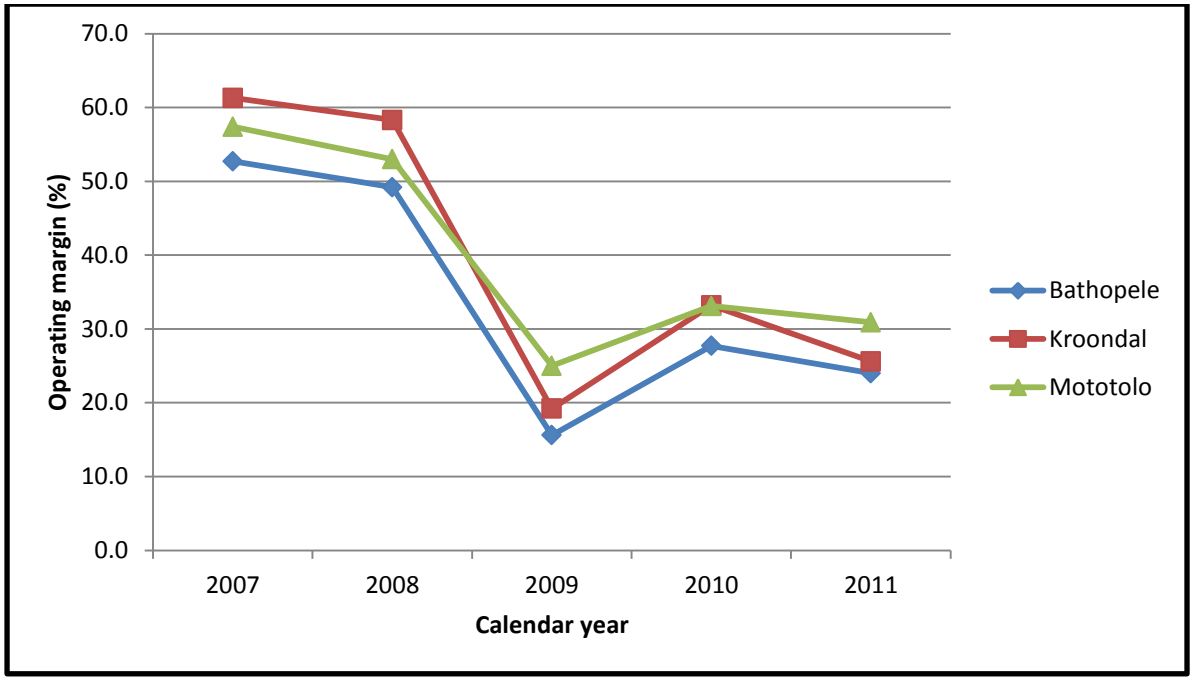


Figure 15: Operating margins between 2007 and 2011 (Anglo American Platinum Limited, 2011)

All three mines showed a decrease in operating margin between 2007 and 2009, with the highest drop experienced in 2008/2009 which is in line with the global economic crisis. However, on average, Bathopele had the lowest operating margin across in all years. While operating margin is a useful measure for investors, it is an end measure which does not say much about the efficiency of production. Moreover, it can be argued that margins are unsustainable because they are squeezed by sharply rising costs.

4.2.5. Correlation between operating margin and measures of productivity

While almost all other production data and measures of productivity showed little sensitivity to the 2008/2009 economic crisis, the operating margin seemed very sensitive to that crisis. This means, the operating margin is a function of price and exchange rate, making it sensitive to changes in the free markets. Thus, while direct sensitivity was not visible in other measures, it is important to determine the relationship between other

measures and the operating margins, thereby establishing whether it is possible to find some relationship between these measures and the free market. Therefore, this section aims to establish and explain any correlation between measures of productivity and operating margins. Table 6 shows the correlation coefficients between:

a) Square metres per total operating employee per annum and operating margin;
b) refined platinum per total operating employee and operating margin;
c) cash-on-mine cost per tonne broken and operating margin;
d) cash operating costs per equivalent refined Pt oz and operating margin;
e) cash operating costs per refined Pt oz and operating margin.

Table 6: Relationship between productivity and operating margin

	Correlation coefficient:				
Mine	**a**	**b**	**c**	**d**	**E**
Bathopele	0.10	-0.29	-0.59	-0.67	-0.47
Kroondal	0.48	-0.59	-0.58	-0.72	-0.65
Mototolo	0.70	0.68	-0.60	-0.71	-0.73

Source: Anglo American Platinum Limited, 2011

There was a weak correlation between square metres mined and operating margin at Bathopele. However, Kroondal and Mototolo showed a moderate correlation between square metres mined and operating margin. This could mean that the operating margin is not a degree of flexibility (availability of reserves) at Bathopele, most probably because there were hardly any geological disturbances encountered. On the contrary, Mototolo's

Borwa shaft has a great deal of oxidised ground and this causes a lot of geological instability and affects the tonnages mined as well as the operating margin.

Mototolo showed a moderately strong correlation between refined platinum per employee and operating margin, whereas, Kroondal showed a moderate negative correlation and Bathopele showed a weak negative correlation. Profit is calculated as the difference between revenue and costs. Therefore, the correlation between cash-on-mine cost per tonne milled, is negatively but moderately to strongly correlated to the operating margin. This means, the higher the costs the lower the operating margin under stable market conditions. Unit cash operating costs also showed a negative correlation with the profit margin.

Since operating costs are quoted in Rands, they are affected by changes in RSA's inflation rates. However, since prices are quoted in US dollars, it is important to look at trends in both inflation rates. Figure 16 shows the trend in inflation rates between 2007 and 2011.

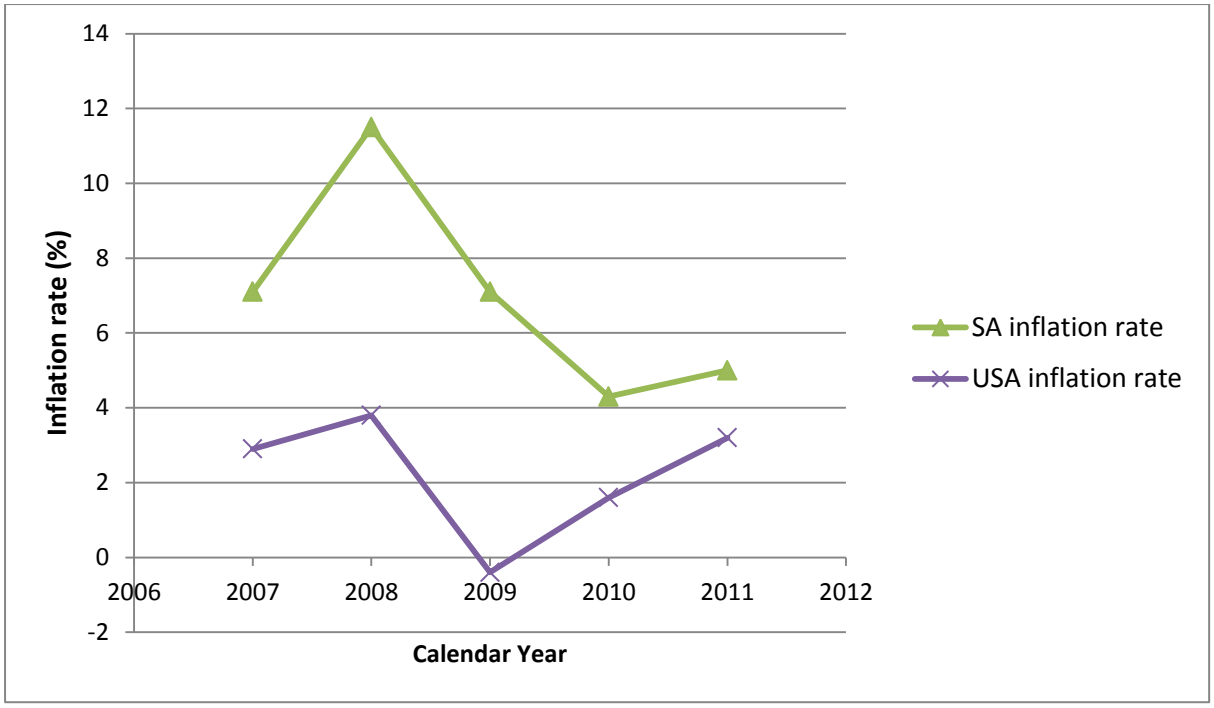


Figure 16: Trend in inflation rates (The World Bank, 2013)

The RSA's inflation rate increased and decreased with a higher gradient than the US's inflation rate. The RSA inflation rate lags behind that of the US, but the gap between the trends appears to be narrowing. A weak positive correlation of 0.353 was found between the two countries' inflation rates. Most measures of productivity showed no correlation with the US inflation rate but showed some correlation with the RSA inflation rate especially the unit costs. This is because unit costs of mining are measured in Rands and just like other costs they too will change with changes in inflation rate.

The general perception is that costs should increase at the same rate with an increase in inflation rate. However, the South African mining industry currently operates in a highly unionised environment whereby union demands are not necessarily based on inflation changes (see Figure 29). Therefore, a decrease in inflation will not imply lower cost mainly

because fixed cost components such as labour, increase with union negotiations. Therefore, a need can be identified for a new, efficiency-based remuneration mix for all employees.

Other fixed cost components such as electricity and water also generally tend to increase each year. With labour unrest characterising most working environments, providers of these services need to factor in their labour costs as well, thus service cost are also increasing.

The platinum price increased steadily between 2007 and 2008 before it sharply fell between 2008 and 2009 as shown in Figure 17. The price then started rising again from year 2009 to 2011. There is interdependency between platinum price and demand and supply. This means when there is an oversupply of platinum, the platinum price drops.

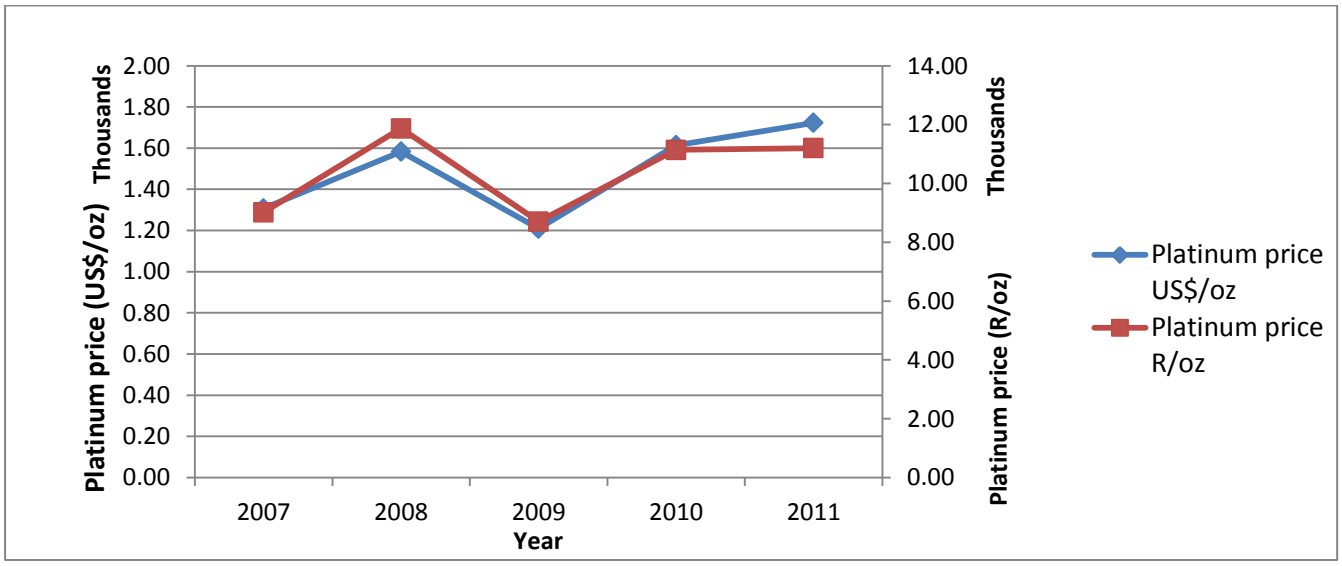


Figure 17: Trend in platinum price (Kitco Metals Inc, 2013)

Figure 17 also shows the gap between platinum price in US$/oz and in R/oz. It is important to note that the platinum price in R/oz is highly linked to the strength of the Rand. On average, the Rand was weaker and stronger in 2008 and 2011 respectively. This explains the higher and lower platinum prices (R/oz) in 2008 and 2011 respectively. Since revenue and

profit depend on the commodity price and other market factors, it is important to investigate the relationship between market factors as well as between market factors and measures of productivity. Table 7 summarises the correlation coefficients among noticeable market factors.

Table 7: Relationship between market factors (2007-2011)

Correlations between:	
US inflation and platinum price	0.62
RSA inflation and exchange rate	0.84
RSA inflation and US inflation	0.35
US inflation and exchange rate	-0.09
Platinum price (US$/oz) and platinum price (R/oz)	0.96

From Table 7, it can be concluded that a strong correlation exists between RSA's inflation rate and the exchange rate. Moreover, a strong correlation also exists between platinum price in US$/oz and platinum price in R/oz. This means local conditions which affect the inflation rate may indirectly affect the exchange rate as well as affecting the profitability of mining operations. For example, labour unrest in RSA may translate into weak economic conditions in the long run, coupled with a weak Rand. Conversely, a weaker Rand will increase the gross revenue, provided the commodity prices are high, these labour unrests also increase the operating costs tremendously, squeezing the overall profit margins. Table 8 shows the relationship between different measures of productivity and market factors by way of correlation coefficients.

Table 8: Correlation coefficients for different measures and market factors (2007-2011)

Correlation between:	**Mine:**		
	Bathopele	**Kroondal**	**Mototolo**
Square metres per total operating employee per annum and operating margin	0.10	0.48	0.69
Refined platinum per total operating employee and operating margin	-0.29	-0.54	0.72
Cash-on-mine cost per tonne broken and operating margin	-0.59	-0.62	-0.66
Cash operating cost per equivalent refined platinum and operating margin	-0.67	-0.75	-0.75
Cash operating cost per refined platinum and operating margin	-0.47	-0.68	-0.76
Square metres per total operating employee per annum and RSA inflation	-0.07	0.53	0.80
Operating margin and SA inflation	0.58	0.60	0.59
Refined platinum per total operating employee and RSA inflation	-0.74	-0.27	0.17
Cash-on-mine cost per tonne broken and RSA inflation	-0.34	-0.44	-0.59
Cash operating cost per equivalent refined platinum and RSA inflation	-0.31	-0.45	-0.47
Cash operating cost per refined platinum and RSA inflation	0.05	-0.27	-0.38
Square metres per total operating employee per annum and US inflation	-0.49	-0.10	0.22
Operating margin and US inflation	0.73	0.69	0.70
Refined platinum per total operating employee and US inflation	-0.55	-0.51	0.33
Cash-on-mine cost per tonne broken and US inflation	0.11	0.14	0.03
Cash operating cost per equivalent refined platinum and US inflation	0.00	-0.06	-0.07

Correlation between:	**Mine:**		
	Bathopele	**Kroondal**	**Mototolo**
Square metres per total operating employee per annum and platinum price	-0.51	-0.30	-0.57
Operating margin and platinum price	0.00	-0.03	-0.06
Refined platinum per total operating employee and platinum price	-0.24	0.21	-0.44
Cash-on-mine cost per tonne broken and platinum price	0.74	0.75	0.78
Cash operating cost per equivalent refined platinum and platinum price	0.66	0.65	0.69
Cash operating cost per refined platinum and platinum price	0.68	0.66	0.66
Square metres per total operating employee per annum and exchange rate	0.39	**0.83**	0.58
Operating margin and exchange rate	0.32	0.37	0.33
Refined platinum per total operating employee and exchange rate	-0.33	0.19	-0.11
Cash-on-mine cost per tonne broken and exchange rate	-0.45	-0.59	-0.56
Cash operating cost per equivalent refined platinum and exchange rate	-0.38	-0.49	-0.44
Cash operating cost per refined platinum and exchange rate	-0.03	-0.35	-0.32

Table 8 continues

Operating margins showed a moderate correlation to South African inflation and US inflation respectively.

The main reason for the fairly strong relationship between operating margins and the US inflation rate is that platinum prices are quoted in US dollars and are therefore subjected to US market conditions. While operating costs continue to rise, most mines still maintain a positive operating margin. This is due to the presence of by-products which are a function of the mineral reserve and these ratios affect the basket price. This means that the operating

margin is more controlled by the platinum price than it is by the operating costs. Moreover, the profitability of the mines is largely controlled by the exchange rate.

Most of the variables compared, showed very weak correlation for the three mines under scrutiny. However, in those cases from Table 8 where all three mines showed strong positive or negative correlation implied some sensitivity of one measure to another. An important example is the strong correlation between cash costs and platinum price. While it can be argued that it is a strange relationship, it is significant and needs to be managed.

4.2.6. Productivity drivers

Several authors have identified and discussed factors affecting productivity. For example, Topp et al (2008) attribute more costly production to low productivity in circumstances where the capacity of mines is constrained. Most mines are running at near or full capacity, therefore output can only be increased in the short to medium term by using more labour and intermediate inputs per unit of output (Topp et al, 2008). Consider Bathopele mine which has maximum hoisting capacity of 280 kilo tonnes per month (12 x 280 = 3, 360 kilo tonnes per year). Using the average number of employees at Bathopele between 2007 and 2011, maximum hoisting capacity per employee was calculated to be 1.5 kilo tonnes per employee. For simpler calculations it was assumed that tonnes hoisted are equal to tonnes milled. Table 9 shows the actual hoisted tonnes per employee.

Table 9: Hoisted tonnes per employee

Year	2007	2008	2009	2010	2011
Hoisted tonnes (kilo tonnes)	2587	2776	2962	3107	2440
Average number of employees	1966	2307	2305	2176	2221
Hoisted tonnes per employee (kilo tonnes/employee)	1.3	1.2	1.3	1.4	1.1

Source: (Anglo American Platinum Limited, 2011)

Using Table 9, Figure 18 was drawn to illustrate the effect of capacity constrain on productivity, in particular, labour productivity.

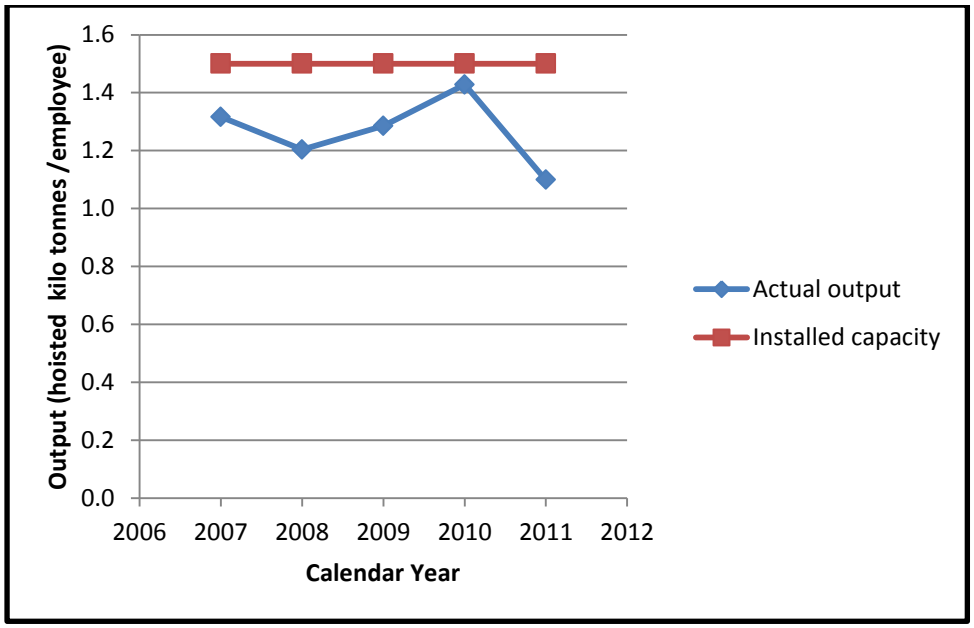


Figure 18: Capacity constraint at Bathopele (Anglo American Platinum Limited, 2011)

Figure 18 compares the installed hoisting capacity of Bathopele with the actual output achieved between 2007 and 2011. Figure 18 confirms argument(s) made by Topp et al (2008) above. In years like 2010, where actual output is close to installed capacity, productivity can only be improved by introducing more technology and reducing labour which is against labour legislation. This means labour legislation and other government policies pose constraints on productivity improvement. Moreover, concurring with Roussos (1996), Aljuhani (2002) identified the following human factors affecting productivity in the mining industry:

- Labour utilization and labour productivity
- Labour/management relations
- Labour/labour relations and

- The crew quality

Labour utilization and productivity are directly affected by equipment availability. However, while the latter is often fairly accurately predicted, based on some measured/real data, measuring labour utilization is often not done and estimations are made. While these estimations probably form a fair guideline for planning and other purposes, it is important to find accurate ways to measure labour utilization in the mines.

According to Roussos (1996), management was generally seen as inflexible and lacking in imagination, creativity and management skills. Management was perceived to be out of touch with realities of the face and authoritarian. Furthermore, in many organisations there is lack of trust between management and workers. The mining industry has increasingly become highly unionised and has been subjected to industrial actions recently.

In 2011, industrial action took place in the form of strikes in the coal and gold sectors. However, labour representatives and the Chamber of Mines handled the wage negotiation process smoothly and in both cases two-year wage agreements were signed (Chamber of Mines, 2010/2011). During the same year, the Youth League of the African National Congress called for nationalisation of the mines, a call which concerned foreign investors (Chamber of Mines, 2010/2011). In 2012, there was widespread labour unrest in the mining industry especially in hard rock mining, platinum in particular.

Without over simplifying or ignoring the root causes of these incidents of unrest, they are an indication of the lack of trust between management and employees. With continued union pressures and labour issues, lack of trust extends further back amongst employees, which has led to some union members losing trust in union representatives. Therefore, there is a

need to achieve employee and organisational goal alignment. While root causes of these labour unrests are unknown, it is important for mining companies to establish effective measures of productivity which among others take cognisance of such human factors.

In cases where agreements between unions and companies have been reached to increase salaries, these agreements have proved to be beneficial, but only in the short to medium term. Companies have invested in and to a certain extent succeeded in the ABET programmes. However, it is clear that the recent labour unrest is also an indication of the conflict between companies' goals and expectations of employees which are perhaps amplified by lack of education. Roussos (1996) stated that, lack of education amongst workers is an important barrier to productivity because poorly uneducated employees:

- Have low literacy rates
- Low skill base
- Lack of understanding of business principles
- Lack of understanding of how workers fit into a productive workplace, or why productivity is important.

Roussos (1996) further argued that some culture/language/values can also hinder productivity. These include but not limited to:

- The lack of common values
- Different attitudes/cultures to/ of work
- Different political/ideological values and beliefs
- Linguistic barriers to effective communication

According to Topp, Soames, Parhan and Bloch (2008), for new projects or during the re-capitalisation of existing projects, long lead times between investment in new capacity in mining can lead to short term movements in mining MFP unrelated to underlying efficiency. Furthermore, depletion of resources has a longer term effect on mining productivity, but this could be offset by technological advances and improved management practices (Topp et al, 2008).

The degree of mechanisation and automation of mining equipment as well as scale of scope are also factors which play a role in improving productivity. Lower commodity prices and temporary idle capital; generally lower productivity (Topp et al, 2008). However, lower commodity prices may also force mining companies to cut costs. If cost cutting is coupled with improved throughput, an improvement in productivity would be observed (Topp et al, 2008).

Higher commodity prices also often result in large increases in the value of output as well as in income (Topp et al, 2008), despite the fact that these high prices have not induced a proportionate increase in the volume of mining output. This is due to substantially increased usage of capital and labour inputs has been accompanied only a modest increase in output, multifactor productivity (MFP) has fallen (Topp et al, 2008).

Overall, most mines experience high variances in the time workers are paid for and the actual productive time. As observed at several mines visited, shorter effective shift time is caused by: longer meetings than planned and late starts thereof; long travelling time to the work stations; unauthorised breaks due to lack of self-discipline and early work stoppages to mention but a few.

The legal actions taken by the Department of Mineral Resources (DMR) against non-compliance with regulations such as section 54 and/or section 55 also affect productivity. For example Lonmin Public Limited Company (Plc) was issued a section 54 and lost 177, 000 tonnes in production across all operations during the quarter which ended on 31st December 2011 (Lonmin Plc, 2012). Anglo American Platinum Limited (2013, p2) also reported that "Platinum production at the Tumela and Dishaba mines decreased by 10% due to shortages of production crews and supervisors and Section 54 safety stoppages." While these losses in production translate into lower tonnes per employee, it also affects unit costs because during closure fixed costs such as labour have to be paid while no revenue is generated.

While the detailed safety stoppages were not obtained for the mines studied due to limitation in scope of this project, Figure 19 shows the number of fatalities at the three mines.

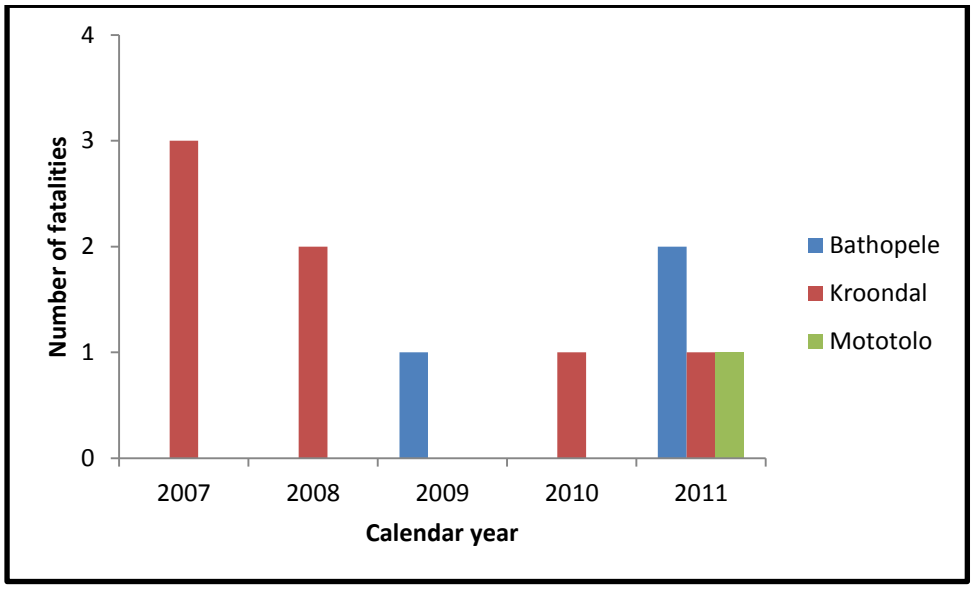


Figure 19: Number of fatalities 2007 – 2011 (Anglo American Platinum Limited, 2013)

The Department of Mineral Resources' section 54 is not only issued for fatal accident, but Figure 19 shows the obvious cases where it is issued. As exemplified with the Lonmin case above, these incidents had an impact on production and productivity thereof. Therefore, some delays such as safety meetings cannot be avoided, but time spent can be improved. Time spend can be improved by giving incentives which incorporate among others health and safety, productivity as well as degree of plan compliance, provided the plan is good. The next Chapter then discusses the reward system used for Senior Executives of Amplat and the workforce at Bathopele.

4.3. Conclusion

Measures of productivity are highly linked to production parameters. However, while production parameters are a reflection of the size of an operation or company, productivity measures the effectiveness of translating input resources into output products. This Chapter found Bathopele and Kroondal to be bigger than Mototolo in terms of area mined, tonnage milled as well as refined platinum.

Chapter 4 further found high negative correlations between: cash-on-mine cost per tonne milled and operating margin, and cash operating costs per equivalent refined Pt oz and operating margin. This shows how sensitive mining is to input costs. Therefore, there is a need for an optimal short term plans as well as a need to control operating costs. Operating costs are characterised by fixed and variable costs. A high proportion of fixed costs are labour costs and this means that fixed costs are vulnerable to labour unrest as well as to the health and safety stoppages. This makes it necessary to effectively utilise and compensate labour. The next Chapter discusses compensation of labour in the mining industry.

CHAPTER 5: AMPLAT REWARD SYSTEM AT DIFFERENT EMPLOYMENT LEVELS

While productivity is a measure of production efficiency and effectiveness of using input resources, it is important that it is aligned with a good short term mine plan. Bonuses are currently awarded, based on meeting short term plan targets. This necessitates further research into measuring short term plan compliance and efficiency in hard rock mining.

Mining companies are very split in their approach to giving allowances and bonuses (Hay Group, 2012). Some companies use flat amounts per salary grade and others use a sliding scale based on internal calculations. This Chapter was intended to explore the salary structures of the three mines and how they incorporate productivity into their remuneration structures. However, due to confidentiality and ownership aspects of financial information, it was only possible to analyse Bathopele mine. The Chapter further seeks to establish the ratio between fixed/basic salaries and bonuses and assess the potential impact of these ratios on productivity.

5.1. Short Term Planning

Mineral resource management (MRM) has been the focus of the SA mining industry with the aim to integrate previously isolated technical functions such as geology, survey, mine planning (Macfarlane, 2006). Macfarlane (2006) further argued that, while the implementation of MRM within various companies has been a success, with visible improvement in the planning processes, there is still poor delivery on plans and projects.

Literature revealed that plan compliance can be and is, measured in coal mining. Plan compliance is divided into three categories: spatial compliance, tonnage compliance and plan performance. However, further research is required to understand the variances between what is planned and what is done at the stope as well as to assess the possible

impacts. Further research is also required to quantify plan compliance and its impact on health and safety.

Apart from infrastructural assets such as the plant, the mineral resource is the fundamental asset of any mining company (Smith et al, 2006). This means all level of planning are ultimately directed towards realising maximum value from this asset under prevailing constraints. Citing Smith (1992), Mohloki and Musingwini (2010) defined planning as the specification of a future course of action to achieve defined objectives within given constraints.

As such, short term planning involves setting out the day to day activities aimed at achieving daily as well as monthly targets, which are often of a volumetric nature. These activities clarify the mining block to be extracted, specific area to be mined, tonnages to be moved as well the allocation of resources. Furthermore, these activities are set out such that they optimise economic return by maximising the net present value in line with company's strategic objectives.

5.2. Background of bonus system in mining

The mining industry has a history of being a high risk environment with harsh working conditions. However, within RSA the mining industry is the leading employer of semi-skilled to unskilled workers. These conditions combined with pressure to compete in international markets called for some form of approach to encourage the employees. The mining industry consequently adopted a motivational strategy of giving production bonuses. This strategy comprises benefit-sharing when ore has been moved and money has been realised. However, the author believes that production is not a true reflection of real performance and the basis for bonuses should be revised.

According to the Hay Group (2012), mining has suffered from shortage of skills for decades now and this has led to increasing premiums and high competition for skilled workers within the industry and across other industries. Mining companies have also become more cost conscious than ever, partly because they are vulnerable to rising input costs such as labour costs, electricity and fuel prices.

Moreover, the industry has become highly unionised, with unions often demanding salary increases. Although salary increments are sometimes informed by increase in inflation and other prices such as accommodation, sometimes these demands are misinformed by perceptions of commodity prices and profit margins reported by companies.

In terms of basic salaries the mining industry is faced with three major challenges: 1) offering competitive salaries to retain skilled workers; 2) bargaining frequently with unions to increase salaries across the board especially for unskilled workers and 3) structuring realistic salaries for workers who are expected to work in an ever increasing hostile underground environment. Such challenges give rise to further challenges with demands by unskilled workers having severe effects if they resort to striking. These demands are often also more complex than they are perceived to be, due to the fact that semi-skilled to unskilled workers do not fully understand the strategic goals of the company, nor do they understand the importance of performance efficiency.

The mining tradition of rewarding volumes mined has been the simplest way of setting up a production related bonus, because even a layman can understand the basis for the reward. Figure 20 illustrates the different types of additional bonuses in the mining industry. In the face of uncontrollable costs of mining, mining efficiencies are often declining or at best

fluctuating. There is a need to adjust the basis for bonuses to suit the changing economic conditions as well as the fluctuating production efficiencies.

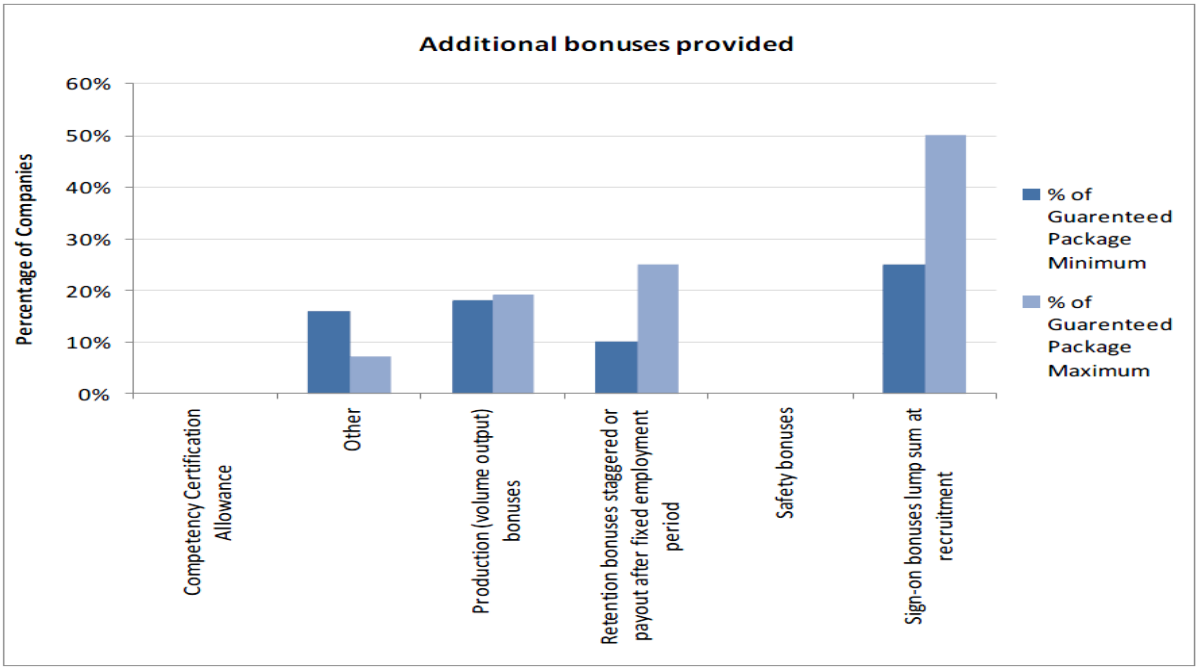


Figure 20: Current bonuses awarded in mining (Hay Group, 2012)

Figure 20 also confirms that volume-based bonuses are still the order of the day with about 20% of the participants in the Hay Group survey indicating that they received production bonuses. Cited by Hay Group (2012), Global Mining Compensation Survey for 2011 found several relevant and critical themes in the mining industry which need to be dealt with. It is important to note that from this survey no safety bonuses were recorded. However, it can be argued that safety bonuses are often compounded into other bonuses such as production bonuses.

One of the most important of these, recognised by the survey is the need for a competitive edge in mining rather than merely paying for employees' work attendance. Often short term mine planning is done and represented in terms of metres to be advanced, areas to be

mined as well as volumes and/or tonnages to be moved. These are the production targets which employees on the ground aim to achieve and if they achieve above these targets they are often rewarded.

There is a need to plan and translate these figures (production targets) to incorporate productivity and rather reward efficiency as opposed to mere volumes. For example, a mine which has 2000 employees and wishes to produce 15 000 ounces of platinum per month should translate this into 7.5 ounces per employee. This requires educating employees to understand the basic but complete mining value chain and their role therein for them to understand their productivity. Furthermore, other conditions should be imposed, based on profitability such that a bonus is based mainly on performance as well as taking market conditions into account. A sliding formula can be developed and be used, possibly a subject for further research.

Amplat does not publicly report how productivity is rewarded at different mines for different employees. However, Amplat reports the remuneration mix for the CEO and other executive directors. Figure 21 shows the composition of these remunerations for 2011.

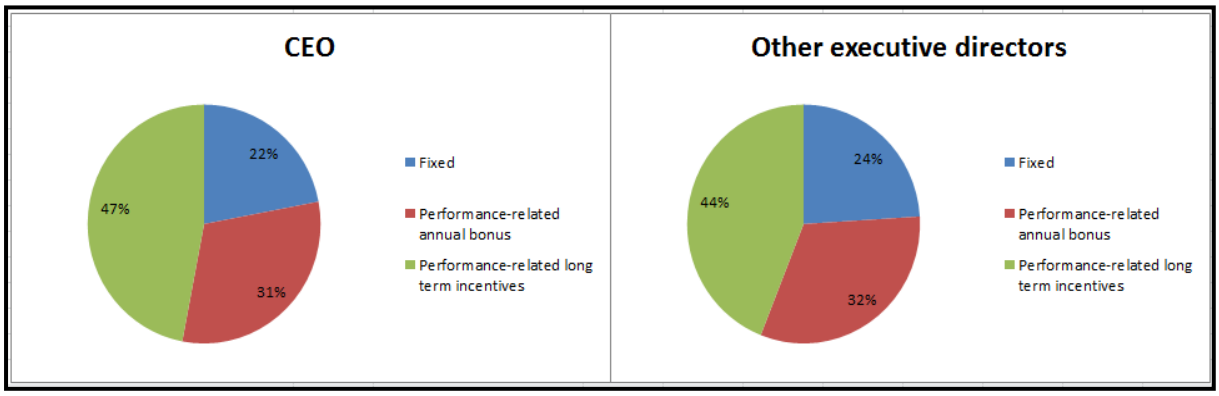


Figure 21: CEO and Executive directors' remuneration mix 2011 (Anglo American Platinum Limited, 2011)

These remuneration mixes vary year on year and are based on the bonus share plan (BSP) and long term incentive plan (LTIP). “The BSP and the LTIP are designed to align the longer term interests of shareholders with those of executives and to underpin the Company’s performance culture” (Anglo American, 2005). Productivity-based reward is easy at this level, because of the level of education of the persons being rewarded.

5.3. Remuneration mix at selected mine(s)

Most employers generally have a tested approach on how to compensate employees. Due to the competitive nature of the mining industry as well as the sensitivity of salary issues, especially during the period of this research, not all selected mines were able to provide the salary information. Therefore, this section will only provide an analysis of data from Bathopele mine.

The year 2012 was highlighted by violent strikes in the industry, the fundamental causes of which are yet to be studied, analysed and addressed. However, these strikes damaged trust in various quarters, ranging from trust between the employers and employees, trust between government and its people as well as trust amongst employees themselves. It further emerged during this period that the government struggles to strike a balance between employment retention and retaining and/or attracting investments.

Moreover, the labour unrest and mistrust among different stakeholders in the industry can also be seen as a conflict in goals. While conflict in goals leads to unmotivated employees, and directly affects labour productivity, it also indirectly affects all other types of productivity. The over reliance on human beings as a major input resource in the mining industry is clear and emphasises the need to use human capital efficiently while investing

into research, development and innovation in order to improve productivity by providing better and safe underground conditions.

While labour union demands are often not precisely justified, the hostile underground working conditions at some mines cannot be underestimated. This study focused on mechanised platinum mines which are also fairly shallow. Therefore, employees at these mines are not exposed to very high levels of heat and they are also unlikely to experience seismicity. However, there is a need to study how these employees are affected by their working conditions especially the psychological impact which affects their motivation to work. The author believes this labour unrest should be investigated further to determine the fundamental causes and understand the message(s) in them.

During the strikes of 2012, it also emerged that employees often focus on short term remuneration which is the money they take home. This does not take into account the amounts spent by employers in ensuring that their employees enjoy other benefits such as medical aid and pension funds. The importance of medical aid cannot be over emphasised as it directly affect productivity due to increased labour availability and supposedly labour utilisation. The general breakdown of the financial remuneration at Bathopele consists of: basic salary, bonuses and other benefits.

Figure 22 shows the trend in the average remuneration components between 2007 and 2011. While Figure 22 shows a true reflection in terms of percentage and ratio changes in the remuneration components, the numbers were normalised. This was done to protect confidentiality of the financial information obtained. This was done by making the year 2007 the base year, meaning basic salaries, bonuses and other benefits in each year were divided by 2007 basic salaries, bonuses and other benefits respectively.

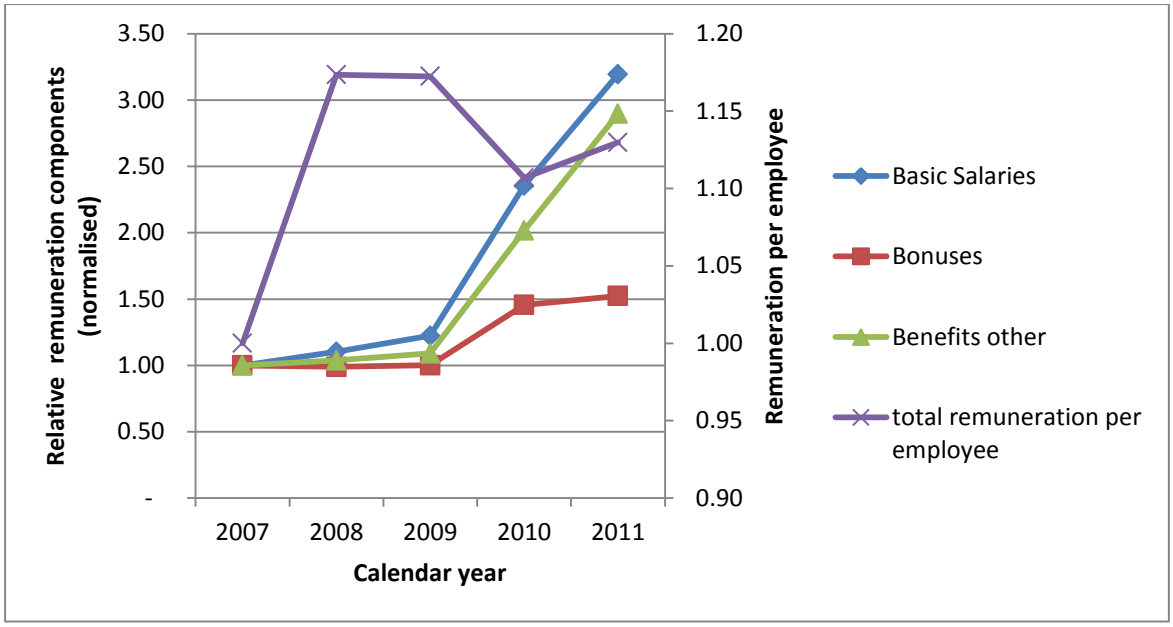


Figure 22: Remuneration mix and total remuneration per employees at Bathopele (Oelofse, 2013)

With reference to 2007, all remuneration components showed an increasing trend, with basic salaries increasing three-fold. Overall, the basic salary, bonuses and other benefits increased by about 65%, 16% and 51% respectively, bringing the overall increase in total remuneration to about 54% between 2007 and 2011. In contrast, the overall increase in the number of employees during the same period was only about 13% which explains the total remuneration per employee graph. This shows that Bathopele is highly exposed to labour risks i.e. exposure to abnormal labour practices.

Coupled with the fluctuations in the market, the increments in remuneration can pose a serious threat which can manifest in various forms. The first is that the industry might try to compromise by meeting the union demands for higher wages and then offsetting the increased costs by shedding some jobs which would continue to give foreign investors the returns they expect. The second could be the withdrawal of foreign investors due to

uncertainty caused by the manner in which wages are negotiated. The increased pressure from employees as well as some political drivers may require the custodians of minerals to consider nationalisation. This concept which has already caused mixed feelings among stakeholders, calls for a clear definition and a deeper cause-effect understanding.

The 'violent' manner of wage negotiations is also a reflection of lack of trust and calls for deeper understanding and education. Perhaps it is time to acknowledge that while ABET has significantly improved the level of literacy in the mining industry, it is time to explore investment into basic economics and/or accounting courses as well as ways to build trust. The lack of trust results from conflict between company goals and those of the majority of employees and perhaps more time should be spent on finding alternative ways to align these goals. While employees receive sufficient training to do their jobs, it is important that they understand the importance of quality, productivity and their roles in the company.

The mistrust will continue to exist because it is also a reflection of the gap between the elite and the average citizen. Thus, it is important to have a balanced remuneration mix for employees to ensure that company goals are met without compromising the well-being of employees. Among other things, this remuneration mix should ensure that all employees have access to decent health services which would increase labour availability. Figures 23 to Figure 27 show the remuneration mix at Bathopele for the different years.

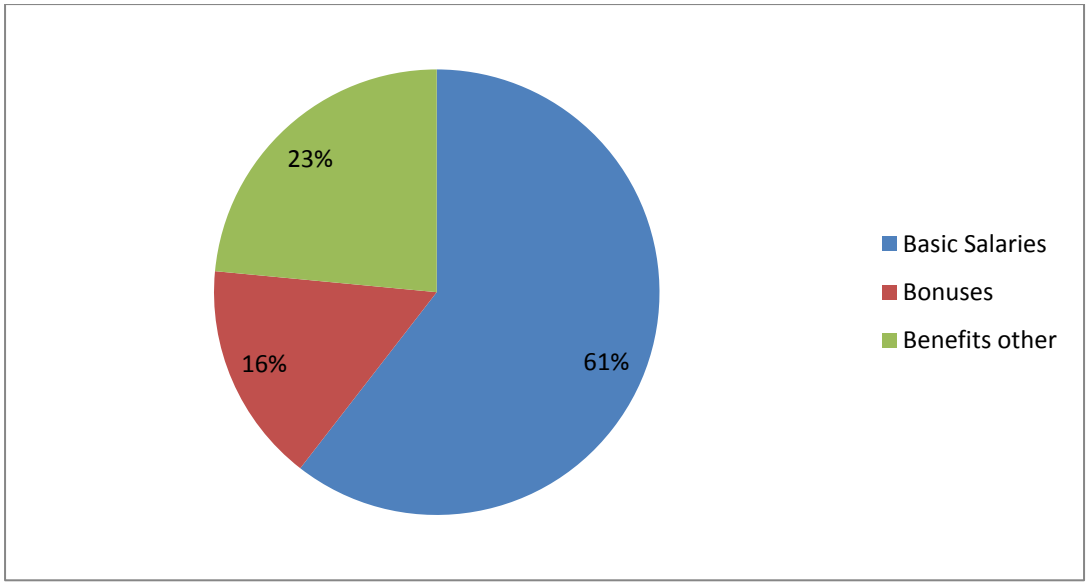


Figure 23: Remuneration mix in 2007 (Oelofse, 2013)

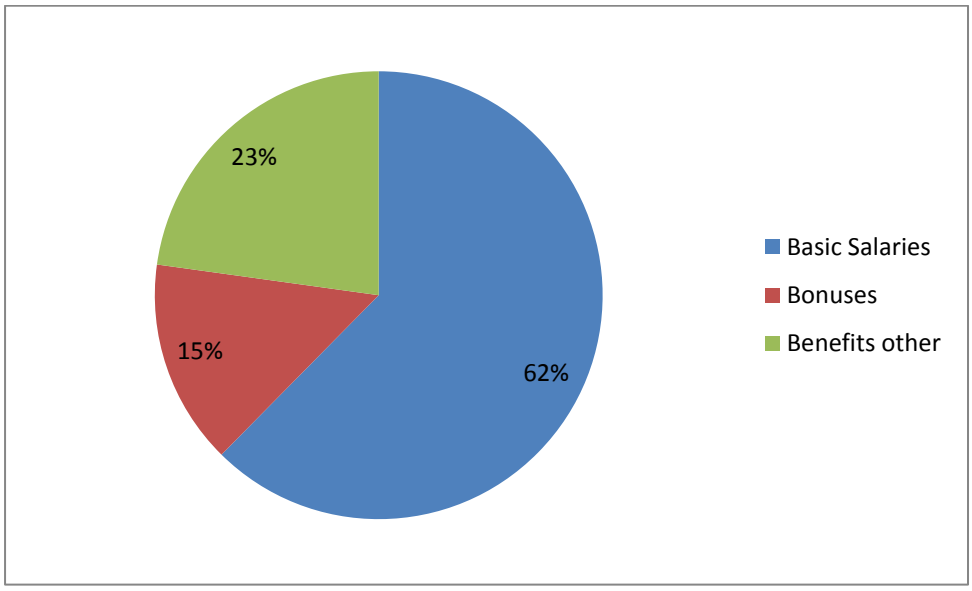


Figure 24: Remuneration mix in 2008 (Oelofse, 2013)

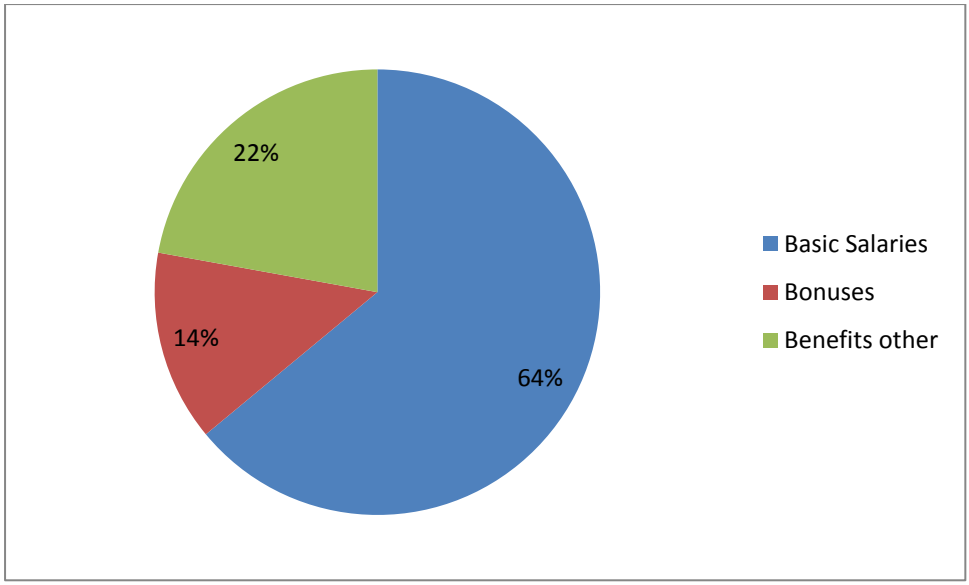


Figure 25: Remuneration mix in 2009 (Oelofse, 2013)

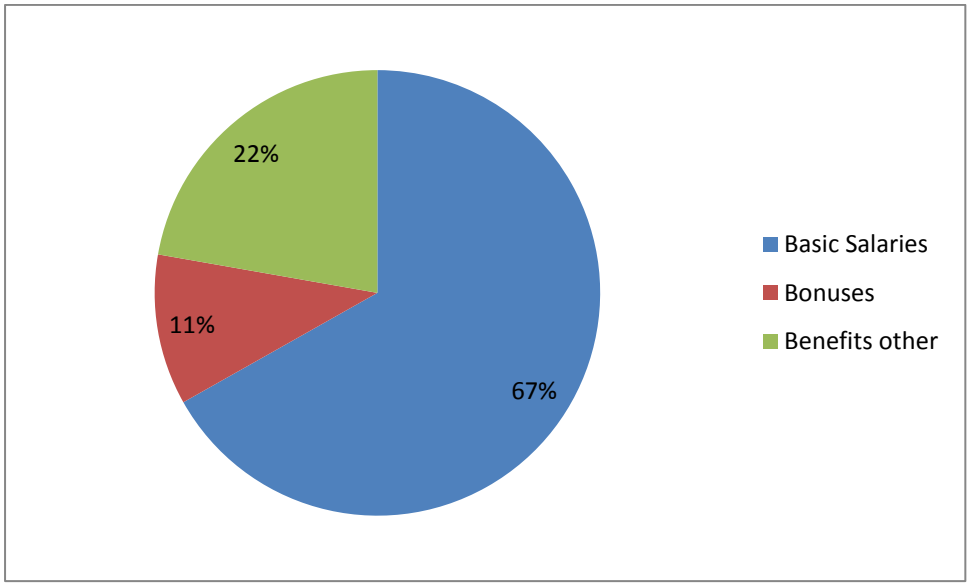


Figure 26: Remuneration mix in 2010 (Oelofse, 2013)

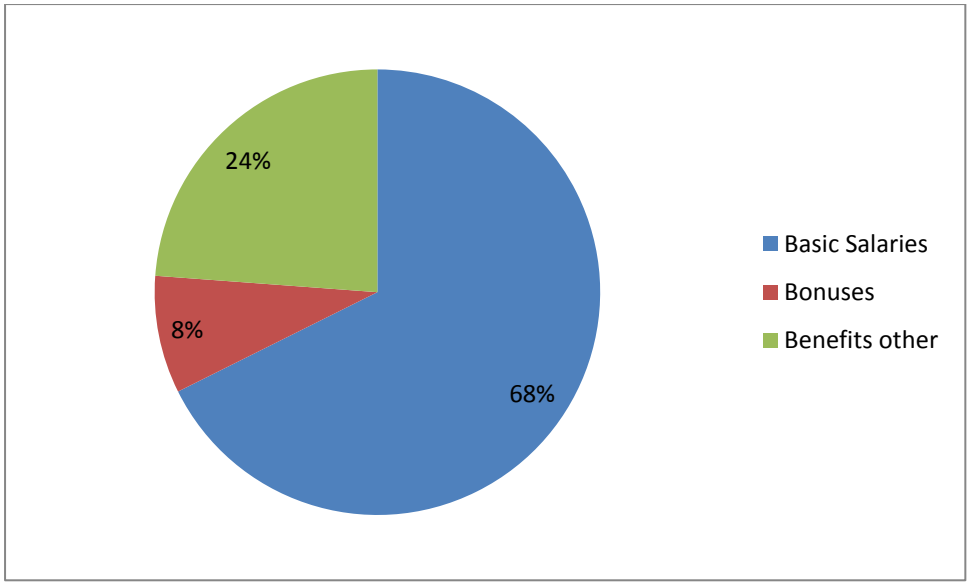


Figure 27: Remuneration mix in 2011 (Oelofse, 2013)

Basic (fixed) salaries ranged between 61 and 68% between 2007 and 2011, showing the highest fluctuation amongst the three components, followed by the fluctuation in the bonus while the other benefits maintained a fairly constant share of the remuneration mix. Basic salaries are paid out irrespective of individual performance and employers generally adjust these salaries annually taking inflation and changes in cost of living into account. However, the pressure exerted by labour disputes on the cash salary (seen in fluctuations in basic salaries and bonuses) cannot be underestimated.

Figures 23 to 27 are a contrast to Figure 21 which shows that over 70% of the CEO and other executive directors' salaries are performance-based. Market fluctuations, labour unrest and political uncertainties are some of the factors which should alert companies to the need to focus on and reward productivity, which would keep the industry competitive and the economy stable. However, employees need to understand their particular roles in the organisation as well as the imperative for efficiency.

There is a need to reward performance without compromising health and safety, perhaps it is time to translate short term plans into measurable forms of efficiencies. The popular volumetric based reward system can be motivating, but could also be quite costly to the employer if not well explained and understood. This means that this type of bonus could promote wrong behaviour and/or substandard completion of a job which could compromise the well-being of the company. It is therefore important to continually ensure that the bonus percentage does not overtake the fixed salary. Table 10 shows the average ratio between the monthly bonus and fixed salary for different categories of employees at Bathopele whereas table 11 relates the bonus percentage to the total cash salary. Total cash salary in this context is the sum of the basic/fixed salary and bonus.

Table 10: Bonus/Fixed salary ratio

Job category/Year	2007	2008	2009	2010	2011
Operators	0.30	0.28	0.22	0.13	0.17
Artisans	0.19	0.19	0.15	0.08	0.08
Junior managers	0.24	0.23	0.21	0.16	0.12
Middle managers	0.27	0.26	0.23	0.18	0.18
Engineers	0.23	0.22	0.19	0.14	0.15
Geologists	0.16	0.16	0.16	0.11	0.10

Source: Oelofse (2013)

Table 11: Percentage bonus of total cash salary

Job category/Year	2007	2008	2009	2010	2011
Operators	23.11	21.65	18.02	11.34	14.62
Artisans	15.92	16.00	13.37	7.73	7.78
Junior managers	19.52	18.86	17.15	13.56	10.95
Middle managers	21.53	20.79	18.79	15.49	15.10
Engineers	18.63	18.19	15.87	12.39	13.39
Geologists	13.83	13.64	13.48	9.94	9.03

Source: Oelofse (2013)

From Tables 10 and 11, the bonus of operators forms a high proportion of their fixed salaries compared to all other categories of employees. A possible reason for this is the direct involvement of operators in production and production based bonuses. Due to the environment in which they work and their level of education, operators are amongst the least motivated employees who generally do not enjoy what they are doing and tend to be on the job due to circumstances beyond their control.

From a few informal interactions with general labour (not at Bathopele), the author gathered that production bonuses keep these people coming to work and their monthly budgets are sustained by these bonuses. While this is a cause for concern due to lack of intrinsic motivation among the general labour force, it is also an opportunity that can be utilised in favour of both labour and industry. In terms of the labour, they could maintain their extra pay, while at the same time being given necessary insights into the need for job efficiency and their role therein. For industry, there is an opportunity to change the bonus model and reward efficiency.

It is common practice for arguments during wage negotiations to be based on inflation changes and hence the changes in the cost of living. Figure 28 shows the year on year percentage increases in the different total remuneration and the SA inflation.

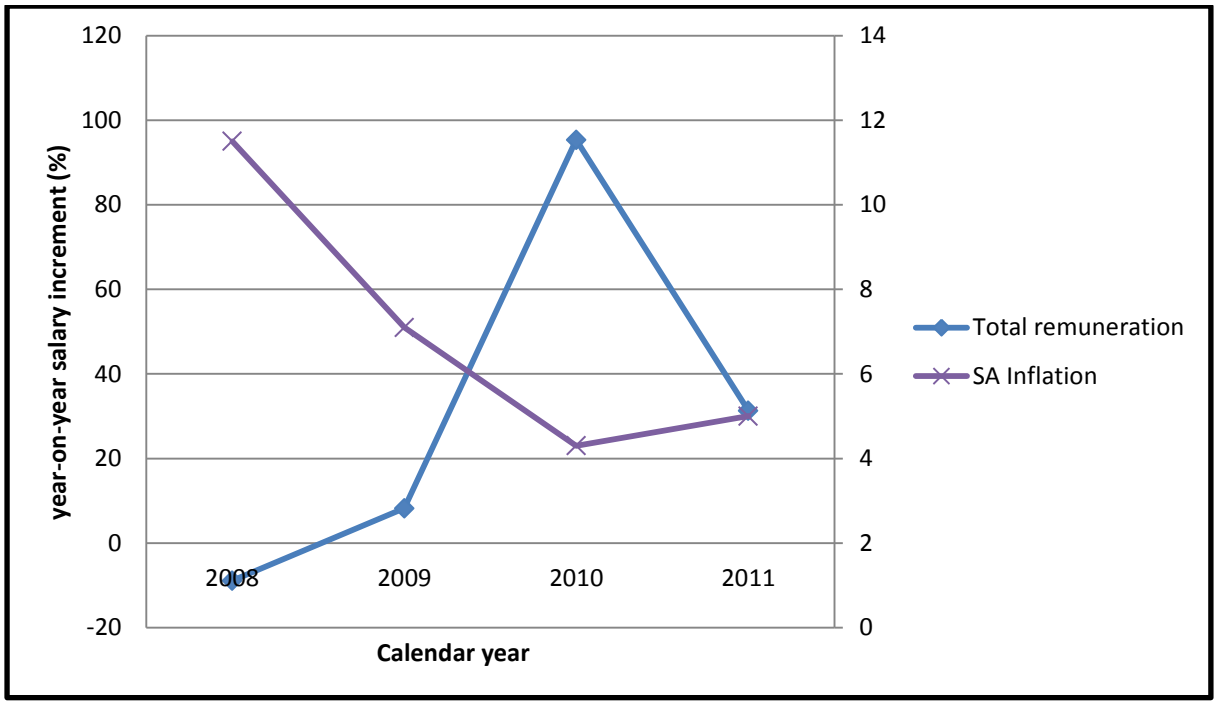


Figure 28: Year-on-year percentage increments at Bathopele and inflation (Oelofse, 2013 & The World Bank, 2013)

Remuneration adjustments and inflation rate show different trends, but they all fluctuate. Remuneration adjustments fluctuate more steeply, in part due to the unionised environment. The overall percentage change in remuneration between 2009 and 2010 was the highest at about 95%. There was a decrease in number of employees between 2009 and 2010. The percentage adjustments were calculated based on total remuneration paid out divided by the average number of employees in service. Therefore, this 95% change is inclusive of money paid out in packages for retirement, resignation and retrenchments.

Figure 28 does not clearly define the relationship between the remuneration adjustments and inflation rate because of the difference in vertical scale. Table 12 shows the percentage increments in fixed salaries for the different categories of employees at Bathopele. Figure 29 shows the trend in average fixed salary adjustments compared with the SA inflation.

Table 12: Year on year fixed salary increments

Job category	**Percentage change (%) between:**				
	2007/2008	2008/2009	2009/2010	2010/2011	2007-2011
Operators	9.09	10.01	6.49	7.01	36.75
Artisans	8.50	10.40	8.50	7.65	39.91
Junior managers	10.60	8.50	8.50	10.23	43.52
Middle Managers	8.50	10.40	8.50	7.65	39.91
Engineers	7.00	10.40	7.50	8.00	37.15
Geologists	7.46	13.16	7.44	9.31	42.81
Average	**8.53**	**10.48**	**7.82**	**8.31**	**40.01**

Source: Oelofse (2013)

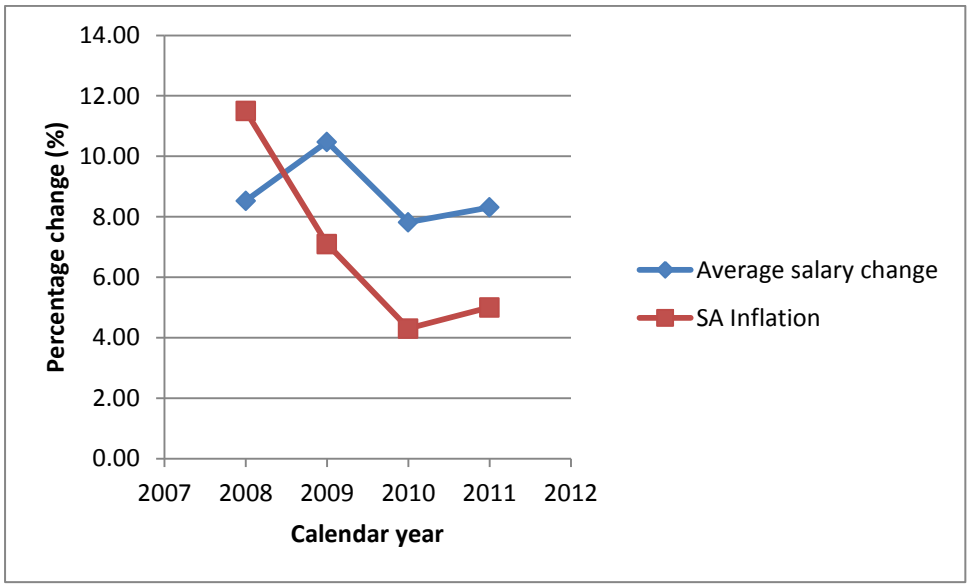


Figure 29: Trend in average salary adjustments (Oelofse, 2013 & The World Bank, 2013)

Overall, salary adjustments followed the trend of RSA inflation, but on average salary adjustments were well above inflation rates. The correlation coefficient between average salary adjustment and the RSA inflation rate was found to be 0.23. This implies a low correlation/relationship between salary adjustments and inflation, so what are the fundamental considerations in wage negotiations and salary adjustments following these talks? Are we currently underestimating the wage adjustments and their impacts on productivity? It may be a coincidence, but it is worth investigating with improved data which would provide better reliability and validity.

5.4. Conclusion

Short term plans were not readily available for this research. Further research is required to assess short term compliance and performance with a view to establishing good practice

and formulating a benchmark. Bonuses are still very production oriented at lower level of employment where productivity is not well understood. Similarly, at lower levels of employment the ratio of bonus/fixed salary shoots up as high as 0.3. The remuneration mix has a direct impact on labour availability and utilisation and on productivity, thus there is a need to align productivity and rewards. The next Chapter summarises the whole report by highlighting major findings and recommendations.

CHAPTER 6: OBSERVATIONS, CONCLUSIONS, RECOMMENDATIONS AND RESEARCH OPPORTUNITIES

The South African mining industry has been characterized in recent years by unfortunate events including incidents of labour unrest and their impacts. Furthermore, being the core of the South African economy, the industry remains under pressure to deliver to all stakeholders bringing about the need to remain effective and competitive. The extent to which RSA's mineral endowment is being translated into a competitive economy which benefits citizens has been questioned. Preceding Chapters conceptualized, gathered and analysed production plus productivity data from selected Amplat mines. This Chapter will highlight the major observations and conclusions drawn from the study. The Chapter will also outline areas for further research.

6.1. Observations and conclusions

This study revealed that there are three common partial measures of productivity: labour, energy and capital productivity. The primary objective of the project was to obtain/understand and analyse the measures already being used by the mines. Expected measures of productivity included: broken/hoisted/milled tonnes per total operating employee; cash cost per tonne broken/hoisted/milled; cash cost per refined ounce of platinum and metres drilled per drill operator per month.

Amplat measured and reported five partial measures of productivity which included, two labour-based and three financial-based measures of productivity. The labour-based were: square metres per total employee and refined platinum ounce per total operating employee. The financial measures of productivity were: cash-on-mine costs per tonne milled; cash operating costs per equivalent refined ounce of platinum and cash operating

costs per refined ounce of platinum. Amplat rewards productivity at higher level of its employment hierarchy, at least 50% of the CEO remuneration mix is performance based.

Irrespective of the measure of productivity reported, data analysis uncovered fluctuating trends in productivity. Fundamental causes of these trends and difference in productivity between three mines studied include: different stoping width, different geology, thus orebody availability and utilisation, grade of the ore milled, different metal ratios. This study further found a moderate to strong correlation between some measures of productivity and market factors. Strong correlation between cash costs and platinum price was found, cash costs can and need to be managed. The author acknowledges that there are other PGMs produced at these mines. However, this project only focused on platinum price. However, further research can establish the correlation among PGMs prices as well as between productivity and all PGMs prices.

Since productivity is a measure of production efficiency, trends in production data were analysed. Major production variables reported by Amplat are: square metres mined, tonnage milled and refined platinum ounces. Due to similarity in geological features in the western limb, Bathopele and Kroondal have similar degrees of flexibility, similar orebodies and orebody grades. Data analysis revealed that Bathopele and Kroondal are relatively close in size as the square metres mined were close in magnitude, but Kroondal produced more refined platinum than both Bathopele and Mototolo. Apart from fundamental causes of differences mentioned above, Kroondal's high amount of refined platinum was attributed to the impact of the DMS on the head grade delivered to the mill.

Mototolo produced averages of about 7% and 18% higher square metres per operating employee than Bathopele and Kroondal respectively. Moreover, Mototolo has also

produced higher platinum per employee and has also been the relative lower cost producer between 2007 and 2011. Mototolo and Kroondal jointly had higher operating margins than Bathopele. Therefore, in terms of productivity, contractor mining has been better than in-house mining during the period of study. It can be argued that employment practices have impact measures of productivity and economic performance on a short to medium terms. Further research is required to establish the impact of employment practices on a long term basis.

Unit costs showed moderate to strong correlations with operating margins, RSA as well as US inflation rates and commodity prices. However, the increased unionised nature of the mining industry could soon see the unit costs decoupling from the inflation rates. Data analysis revealed a link between production parameters: area mined; tonnage milled and refined platinum. A further link was uncovered between operating margin and unit costs.

The level of mechanisation in platinum mining and in hard rock mining is limited due to the geological nature of ore bodies being mined. This makes hard rock mining relatively labour intensive and less effective compared to soft rock (coal) mining. Furthermore, a high proportion of the employees in hard rock mining have low levels of education, and some of their goals are in conflict with company goals. The labour intensive nature of hard rock mining makes it vulnerable to: labour unrests, low labour availability as well as ineffective labour utilisation.

While productivity drivers range from equipment availability to resource (orebody) availability, human factors as identified by Aljuhani (2002) play a major role in productivity. These human factors are currently evident in the continuing labour unrests which reflect anger and mistrust. Other productivity drivers include: technical efficiency such as accurate

drilling, lower dilution; application of technology such as the use of the DMS for pre-processing, mechanisation and automation. DMR' sections 54 and/or 55 stoppages also affect productivity, making it necessary to improve productivity, but within a safe working environment.

Short term planning compliance and performance in hard rock mining is not well documented. The mining industry continues to be amongst the largest employers with a high level of semi-skilled to unskilled labour. The level of education plays a major role in productivity and rewards thereof. On this basis, the mining industry continues to give production and safety bonuses to ensure understanding and avoid possible conflicts with employees. Productivity is linked to production by the number of employees and the number of employees can vary enormously while installed mine capacity (such as hoisting or milling capacity) does not change (unless a serious upgrade is made). Therefore, depending on the number of employees, rewarding production may or may not reward productivity.

The financial data obtained did not have an explanation of the system used to calculate bonuses. Meeting production tonnage or area does not necessarily mean a good short term plan was followed. The author recommends that plan compliance metrics should be calculated for hard rock mining and be included in productivity reward system. Productivity is well understood at higher levels of management and as such the remuneration mixes of the Amplat CEO and directors are performance based. On the contrary, the remuneration mix at lower levels is independent of individual and company/operation's performance.

6.2. Recommendations

No matter how productivity is measured, the values fluctuated. Therefore, there is a need to explain productivity and ensure that it is well understood at all levels along the mining value chain. The South African mining industry needs to be competitive and this requires the industry to be productive at all levels, necessitating productivity improvement at the mines. This sub section highlights what could be done in order to understand and improve productivity in the short and long terms.

6.2.1. Short term recommendations

Both labour-based and financial-based measures of productivity reported are affected by several human related factors. Therefore, the following measures are suggested to improve productivity:

- Increasing labour utilisation as well as effective shift time by periodically providing refresher training to employees.
- Motivate employees to take ownership of their working environment and ensure that they are working safely to avoid safety stoppages. This could be done by:
    - Giving incentives for health and safety as well as productivity.
    - Involving the whole crew (stoping or development team) in hazard identification and risk assessment, allowing them to make reasonable suggestions.
    - Supervisors should take interest in their crew members and support them, things like remembering your employee's birthday and wishing him/her well mean a lot; showing concern on an unusual behaviour.

    - Team building exercises should be conducted so that crew members get to know and understand each other better.
- Investigate the causes of any non-productive time for each employee and take necessary measures to reduce it.
- Increase the production output by effectively using the available resources without drastically changing the number of employees. This can be done by optimising the availability and utilisation of machinery.
- Cash costs need to be managed; a large proportion of these are labour costs. Salary adjustments need to be reasonable; this can be achieved by educating union representatives to understand the business model. Fuel and electricity costs also need to be monitored; this could be done by switching off machines/equipment not in use. Employees' cooperation should be gained by educating them not instructing them.
- Productivity and its benefits thereof should be made clear to employees at all levels.
- Supervisors should closely monitor their teams, reprimand non-productive habits while also acknowledging (not necessarily rewarding) productive habits.

6.2.2. Long term recommendations

While all effort goes into improving productivity on a short to medium terms, the following are suggested for the longer term:

- Employees should be educated what productivity is and what their roles are in individual and overall productivity.
- Employees should also be given basic knowledge of the business model and the concept of value addition.

- More research into mining technology should be done. Perhaps the demands from unions are reflections that while people are only prepared to work under such conditions at amounts which the mining industry cannot sustain.
- Mining methods should also be revised, is the industry locked into these mining methods due to absence of alternatives or poor research or fear of changing and trying other method?
- Just like it is done with unit costs, a benchmark for productivity should be determined to take account of changing drivers of productivity.

Understanding the current way in which productivity is measured and possibly suggest a suitable benchmarking measure especially for comparative purposes. How can fundamental factors such as difference in labour size and range of salaries be dealt with in order to make a fair comparison between productivity in two mines within the same company or even between mines run by different companies.

6.3. Further research opportunities

Then there is a need to shift focus from production to productivity in order to remain competitive and maintain/improve the industry's contribution to the national as well as global economy. Thus, further research is required to define suitable multi factor (total) measures of productivity (as defined in Chapter 2) and to determine all relevant partial measures of productivity to feed into it. Apart from measuring and reporting productivity, there is a need to also investigate productivity growth by commodity and determine drivers of productivity growth.

This research has not answered all questions that the author intended to answer due to limited access to required data. Questions to ponder on in further research include: do all

PGMs prices follow the same trend? Apart from platinum, which of them has the greatest impact on productivity? Further research is also required to increase the number of platinum mines and extend to other commodities to establish an industry analysis and possibly a benchmark.

The number of mines in future studies, needs to be increased to improve validity and determine the real effect of in-house versus contractor mining. Moreover, access to other key production parameters such as mine call factors, grade, stoping width to mention but a few will be required in further research. Cost curves should be continually updated and applied in the mining industry as they take cognisance of some market factors.

Further research is also required to engage different stakeholders to establish the root cause of the evident lack of trust between: industry and government; industry and labour as well as labour and labour. There is also a need to invest into changing mind-sets; change platform to emphasise and increase efficiency; increase the capacity in research and development and innovation thereof.

There were no interviews conducted for this project. However, interaction with drill operators, production miners, development miners, service workers, hoist attendants, rock bolting crew, grade operators is necessary in further work to understand the conditions they work in and how they adapt to ensure productivity. The interaction is also important in establishing the attitude of the employees and possibly their work goals and how they relate to company goals.

Ultimately, productivity is linked to a certain mining method and within limitations of that mining method companies can optimise. However, there is a limit to which this could be

done. Therefore, fundamental research into new mine designs and mining methods is required.

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APPENDICES

Appendix A: Anglo American Platinum Limited 2011 annual report extracts

Source: (Anglo American Platinum Limited, 2011)

BATHOPELE MINE (100% owned)		2011	2010	2009	2008	2007
Refined production						
Platinum	000 oz	**118.3**	141.6	133.6	112.6	116.3
Palladium	000 oz	**65.8**	81.8	73.9	62.7	66.9
Rhodium	000 oz	**20.9**	24.7	25.9	19.6	22.0
Gold	000 oz	**1.3**	1.4	1.5	1.2	1.6
PGMs	000 oz	**243.2**	292.8	278.0	228.9	240.1
Nickel	000 tonnes	**0.3**	0.3	0.3	0.2	0.2
Copper	000 tonnes	**0.1**	0.1	0.1	0.1	0.2
Production statistics						
Total development – UG2	km	**2.4**	–	–	–	–
Immediately available ore reserves	months	**13.7**	13.5	11.5	11.5	13.0
Square metres – UG2	000 m^2	**340**	429	437	401	370
Tonnes – Surface sources to concentrators	000 tonnes	**–**	–	–	–	–
Tonnes broken – UG2	000 tonnes	**2,642**	3,293	3,309	2,925	2,698
Tonnes milled	000 tonnes	**2,440**	3,107	2,962	2,776	2,587
Surface sources	000 tonnes	**–**	–	–	–	–
Underground sources	000 tonnes	**2,440**	3,107	2,962	2,776	2,587
UG2 tonnes milled to total Merensky and UG2	%	**100.0**	100.0	100.0	100.0	100.0
Built-up head grade (gram/tonne milled)	4E	**3.08**	3.02	3.08	2.94	3.02
Surface sources	4E	**–**	–	–	–	–
UG2	4E	**3.08**	3.02	3.08	2.94	3.02
Equivalent refined platinum ounces[1]	000 oz	**112.5**	138.7	131.8	120.1	111.2
Employees and productivity						
Own-enrolled employees (average in service)	number	**1,826**	1,547	1,092	944	826
Contractor employees (average in service)	number	**395**	629	1,213	1,363	1,140
m^2 per total operating employee[2]	per month	**13.1**	16.5	15.6	14.8	15.7
Refined Pt ounce per total operating employee	per annum	**53.3**	65.1	58.0	48.8	59.2
Unit cost performance						
Cash on-mine cost/tonne milled	R/tonne	**558**	436	428	413	300
Cash operating cost per equivalent refined Pt oz	R/oz	**13,168**	10,748	10,647	10,386	7,735
Cash operating cost per refined Pt oz	R/oz	**12,522**	10,528	10,504	11,708	7,396
Operating income statement						
Net sales revenue	Rm	**2,284**	2,526	1,950	2,346	2,202
Operating cost of sales[3]	Rm	**(1,736)**	(1,825)	(1,645)	(1,191)	(1,042)
Operating contribution	Rm	**548**	701	305	1,155	1,160
Operating margin	%	**24,0**	27.7	15.6	49.2	52.7

[1] Mine's production and purchases of metal in concentrate, secondary metals and other metals converted to equivalent refined production using Amplats' standard smelting and refining recoveries.

[2] Calculation based on a standard 23-shift month.

[3] Operating cost of sales excludes other costs.

KROONDAL PLATINUM MINE (50:50 pooling-and-sharing agreement with Aquarius Platinum (South Africa))		**2011**	2010	2009	2008	2007
Refined production (mined and purchased)						
Platinum	000 oz	**217.6**	266.7	230.7	196.3	128.8
Palladium	000 oz	**106.4**	132.4	110.8	94.0	63.5
Rhodium	000 oz	**41.2**	43.1	40.5	30.4	22.6
Gold	000 oz	**1.7**	1.9	2.0	1.3	1.2
PGMs	000 oz	**445.9**	522.7	458.7	371.8	267.0
Nickel	000 tonnes	**0.3**	0.4	0.4	0.3	0.2
Copper	000 tonnes	**0.1**	0.1	0.1	0.1	0.1
Production statistics (AAPL mined share)						
Total development – UG2	km	**11.3**	11.6	–	8.0	10.0
Square metres – UG2	000 m^2	**374**	449	397	407	400
Tonnes broken – Opencast	000 tonnes	**–**	–	–	217	1,852
Tonnes broken – UG2	000 tonnes	**2,859**	3,497	3,374	3,072	2,954
Tonnes milled[4]	000 tonnes	**1,891**	2,154	2,070	2,023	2,217
Surface sources including opencast	000 tonnes	**–**	–	–	10	95
Underground sources	000 tonnes	**1,891**	2,154	2,070	2,013	2,122
UG2 tonnes milled to total Merensky and UG2	%	**100.0**	100.0	100.0	100.0	100.0
Built-up head grade (gram/tonne milled)[5]	4E	**3.75**	3.80	2.58	2.59	2.70
Surface sources excluding opencast	4E	**–**	–	–	–	–
UG2	4E	**3.75**	3.80	2.58	2.59	2.70
Equivalent refined platinum ounces[1]	000 oz	**208.6**	252.8	231.6	213.4	130.3
Mined	000 oz	**104.3**	126.4	115.8	114.4	121.1
Purchased	000 oz	**104.3**	126.4	115.8	106.7	65.1
Sold	000 oz	**–**	–	–	(7.7)	(55.9)
Employees and productivity (AAPL share)						
Own-enrolled employees (average in service)	number	**15**	12	20	17	11
Contractor employees (average in service)	number	**3,332**	2,775	2,855	2,718	2,601
m^2 per total operating employee[2]	per month	**9.1**	13.8	12.7	14.5	12.7
Refined Pt ounce per total operating employee	per annum	**32.5**	47.8	40.1	35.9	24.7
Unit cost performance						
Cash on-mine cost/tonne milled[4]	R/tonne	**726**	595	533	499	339
Cash operating cost per equivalent refined Pt oz	R/oz	**14,093**	11,031	10,437	9,441	6,524
Cash operating cost per refined Pt oz	R/oz	**13,510**	10,455	10,455	10,306	6,871
Operating income statement						
Net sales revenue	Rm	**2,095**	2,202	1,564	2,191	2,090
Operating cost of sales[3]	Rm	**(1,559)**	(1,472)	(1,263)	(914)	(808)
Operating contribution	Rm	**536**	730	301	1,277	1,282
Operating margin	%	**25.6**	33.2	19.2	58.3	61.3

[1] Mine's production and purchases of metal in concentrate, secondary metals and other metals converted to equivalent refined production using Amplats' standard smelting and refining recoveries.

[2] Calculation based on a standard 23-shift month.

[3] Operating cost of sales excludes other costs.

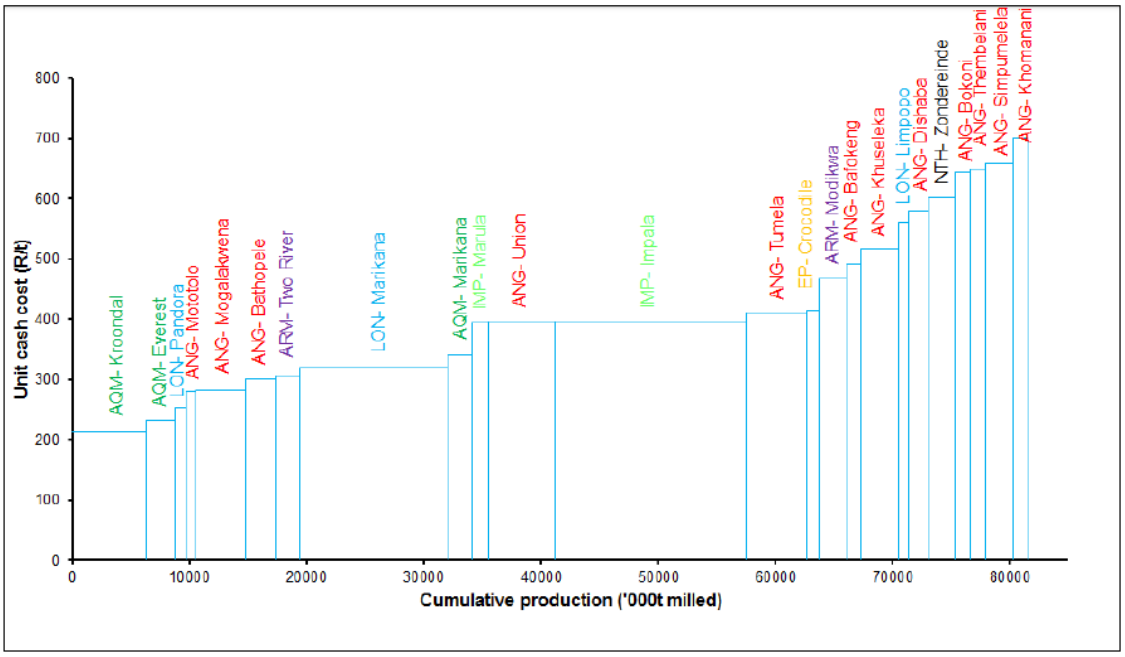
[4] Tonnes milled restated for previous years from DMS feed tonnes to mill feed tonnes.

[5] 4E built-up head grade previously reflected the DMS feed grade, changed to mill feed grade in 2010.

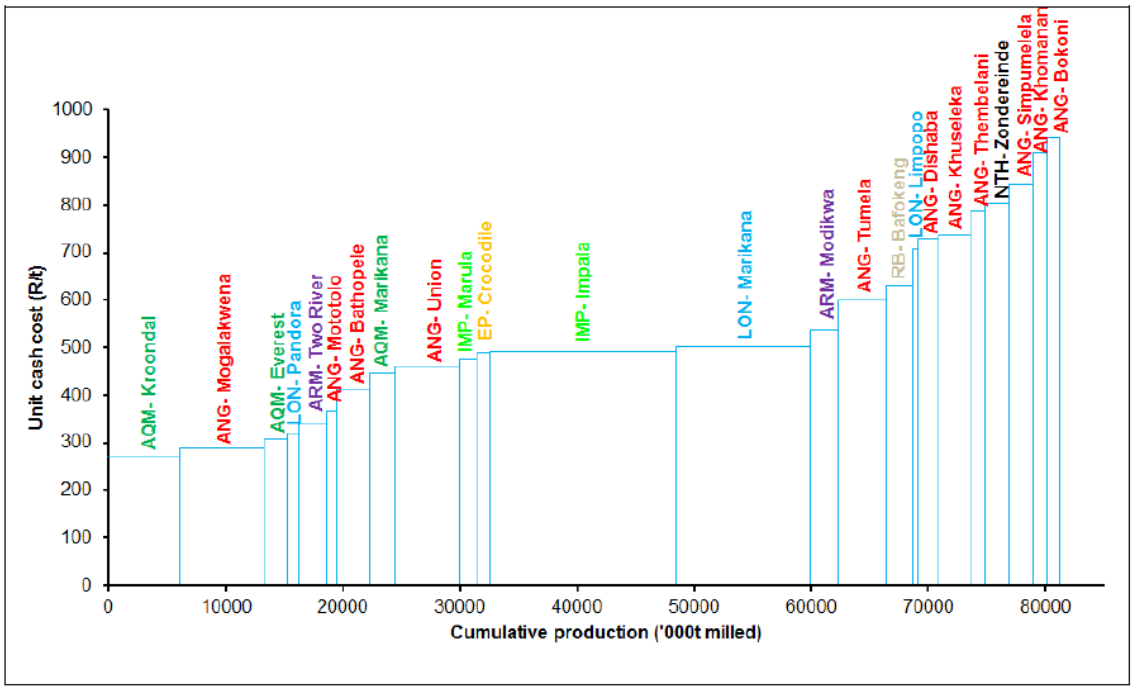
MOTOTOLO PLATINUM MINE (50:50 joint venture with XK Platinum Partnership)		2011	2010	2009	2008	2007
Refined production (mined and purchased)						
Platinum	000 oz	**115.1**	110.5	106.3	83.9	92.6
Palladium	000 oz	**66.8**	65.0	61.5	48.9	55.3
Rhodium	000 oz	**17.8**	18.7	17.2	13.5	13.8
Gold	000 oz	**1.8**	1.5	1.6	1.1	1.4
PGMs	000 oz	**234.9**	231.9	214.9	175.3	182.4
Nickel	000 tonnes	**0.3**	0.3	0.3	0.2	0.3
Copper	000 tonnes	**0.1**	0.1	0.1	0.1	0.1
Production statistics (AAPL mined share)						
Total development – UG2	km	**1.0**	0.9	1.4	0.9	0.9
Square metres – UG2	000 m^2	**142**	132	149	121	113
Tonnes broken – Opencast	000 tonnes	**–**	–	–	–	–
Tonnes broken – UG2	000 tonnes	**1,188**	1,110	1,247	976	925
Tonnes milled	000 tonnes	**1,151**	1,131	1,120	911	901
Surface sources including opencast	000 tonnes	**–**	–	–	–	–
Underground sources	000 tonnes	**1,151**	1,131	1,120	911	901
UG2 tonnes milled to total Merensky and UG2	%	**100.0**	100.0	100.0	100.0	100.0
Built-up head grade (gram/tonne milled)	4E	**3.27**	3.33	3.42	3.37	3.60
Surface sources excluding opencast	4E	**–**	–	–	–	–
UG2	4E	**3.27**	3.33	3.42	3.37	3.60
Equivalent refined platinum ounces[1]	000 oz	**109.4**	108.0	108.8	87.2	95.2
Mined	000 oz	**54.7**	54.0	54.4	43.6	47.6
Purchased	000 oz	**54.7**	54.0	54.4	43.6	47.6
Employees and productivity (AAPL share)						
Own-enrolled employees (average in service)	number	**698**	670	600	586	548
Contractor employees (average in service)	number	**228**	328	283	86	3
m^2 per total operating employee[2]	per month	**14.2**	13.2	15.8	16.8	17.0
Refined Pt ounce per total operating employee	per annum	**62.1**	55.4	60.2	62.4	84.0
Unit cost performance						
Cash on-mine cost/tonne milled	R/tonne	**494**	438	384	368	280
Cash operating cost per equivalent refined Pt oz	R/oz	**11,800**	10,392	9,132	8,648	6,076
Cash operating cost per refined Pt oz	R/oz	**11,214**	10,155	9,360	8,992	6,249
Operating income statement						
Net sales revenue	Rm	**1,066**	983	727	873	698
Operating costs of sales[3]	Rm	**(737)**	(658)	(545)	(410)	(297)
Operating contribution	Rm	**329**	325	182	463	401
Operating margin	%	**30.9**	33.1	25.0	53.0	57.4

[1] Mine's production and purchases of metal in concentrate, secondary metals and other metals converted to equivalent refined production using Amplats' standard smelting and refining recoveries.
[2] Calculation based on a standard 23-shift month.
[3] Operating costs of sales excludes other costs.

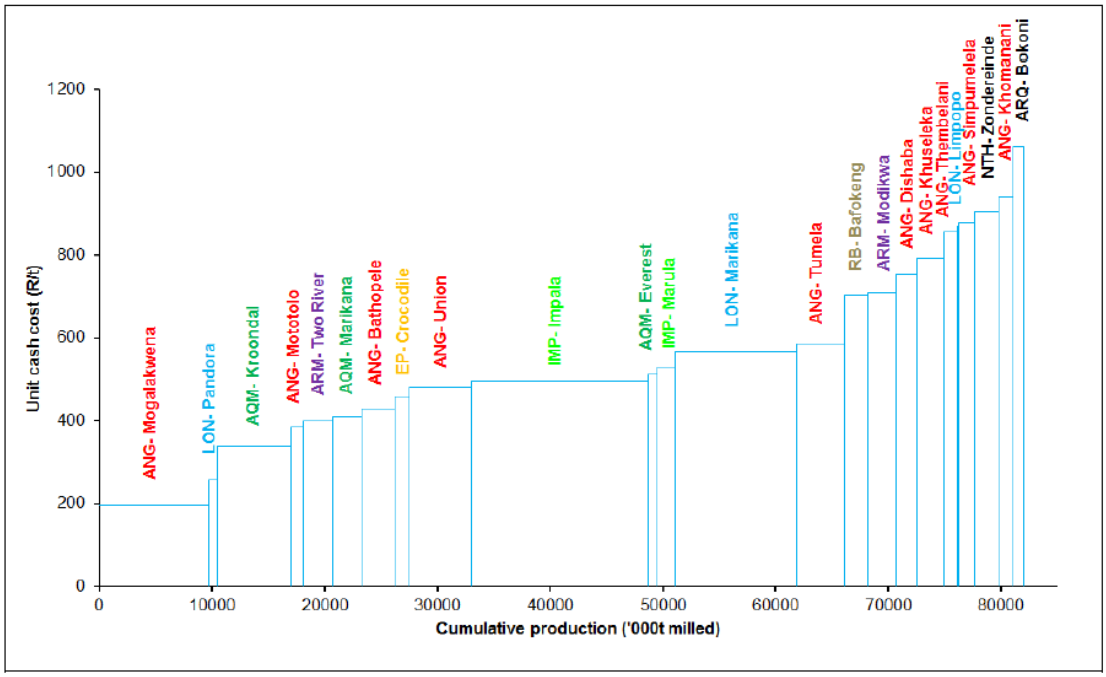
Appendix B: Platinum cost curves 2007 to 2010



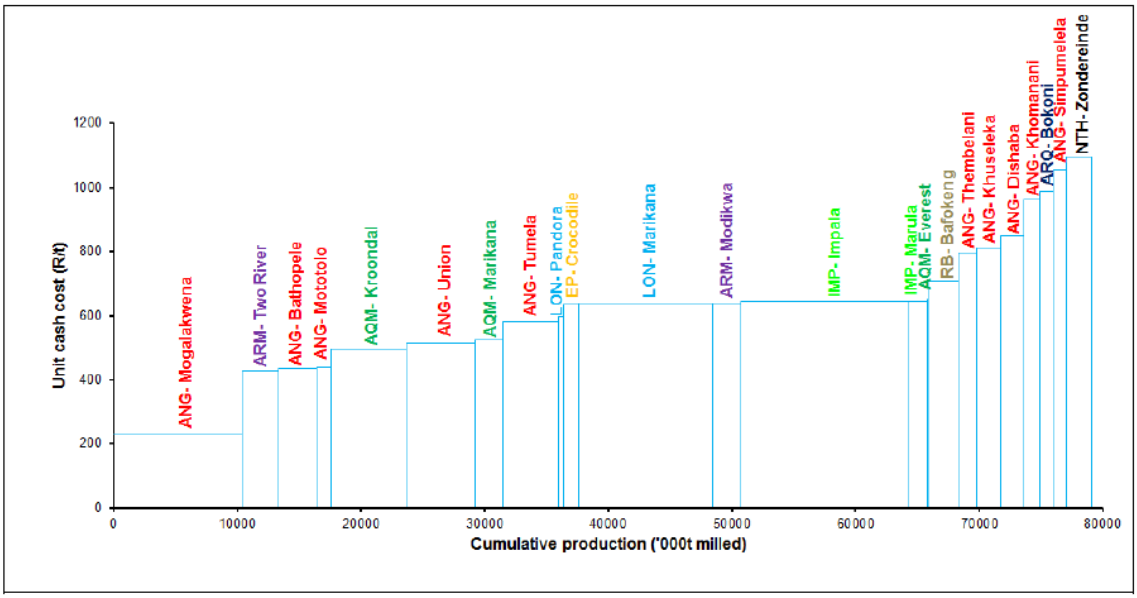
Platinum cost curve 2007 (Tholana, unpublished MSc thesis 2012)



Platinum cost curve 2008 (Tholana, unpublished MSc thesis 2012)



Platinum cost curve 2009 (Tholana, unpublished MSc thesis 2012)



Platinum cost curve 2010 (Tholana, unpublished MSc thesis 2012)