Mining resource optimisation: The effect of the cost application methodology on the value of a project

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To whom it may concern,

LANGUAGE EDITING

This letter serves as proof that the following document was submitted for language editing in November 2015:

Author: Henri de Klerk

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I applied all reasonable effort to identify errors and made recommendations about spelling, grammar, style and punctuation.

I attempted to be consistent regarding language usage and presentation.

The bibliography was also checked and corrections were made where necessary.

I confirmed the content as far as possible, but cannot be held responsible for this as all facts could not be confirmed. This remains the responsibility of the author.

Thank you very much.

Kind regards.

Rentia Mynhardt

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"Geloof versterk dié wat moeg is met krag van Bo."

Audrey Jeanne Roberts

ABSTRACT

South Africa has vast mineral resources and the mining sector has a great impact on the gross domestic product (GDP), gross fixed capital formation (GFCF) and exports. As a result the mining sector employed 2.6% of all the workers in the non-agricultural formal sectors of the economy in 2012. Because of South Africa's dependence on mining as a contributor to the economy, there are many studies conducted annually to determine the economic viability of proposed mines.

During these studies the resource has to be optimised. Optimisation means that portions of the ore that are deemed economic for exploitation should be identified – this portion of the ore is known as the economic footprint. During the optimisation phase costs and prices are applied to the resource. The dilemma in the optimisation phase is how these costs are being applied. Research done during this study has shown that the tendency in practice is to apply benchmarked unit costs for both capital and operating expenditure.

This study focusses on the application method of the variable costs during the resource optimisation phase. Time-driven activity-based costing (TDABC) was identified as an alternative to the traditional costing methodology. In context of the aforementioned the primary research objective of this study was to determine the effect of applying TDABC for the variable costs during the resource optimisation phase instead of the conventional benchmarked unit costs.

During the research done for this study it has become apparent that activity-based costing (ABC) is a managerial costing tool that is more expensive than traditional costing techniques and that it is not required for external financial reporting. ABC purely is a management decision tool! It enables the manager to manage costs by modifying the activities that are used to produce a product or a service. Because of the costliness of an ABC system TDABC was introduced as an alternative to the traditional ABC system. TDABC addresses the limitations posed by ABC – it is simpler, less costly, faster to implement and applies the practical capacity of resources to calculate the costs.

To satisfy the primary objective of the study, a hypothetical coal deposit was constructed in a block model. The model contains 101 million gross tonnes in situ (GTIS) that is reduced to 91 million mining tonnes in situ (MTIS) and 90 million run of mine (ROM) tonnes when the modifying factors are applied. The 90 million ROM tonnes are made up of 35 million tonnes export product, 10 million tonnes domestic product and 45 million tonnes discards.

Value distribution models (VDMs) were constructed to determine the economic footprints of the resource. In total six VDMs were constructed; the variable costs that were applied to each are: VDM 01 uses TDABC principles to calculate the variable costs; VDM 02 recalculates the total

costs obtained from VDM 01 to unit costs; VDM 03 recalculates the grand total cost obtained in VDM 01 to a single unit cost; VDM 04 applies Wood MacKenzie data, based on export and domestic product tonnes, for a similar mine to calculate the variable costs; VDM 05 applies Wood MacKenzie data, based on total product tonnes, for a similar mine to calculate the variable costs; VDM 06 applies benchmark data for a similar mine to calculate the variable costs. The cut-off value that was applied is zero; i.e. blocks with a value of zero and less were excluded from the economic footprint of each VDM.

A production schedule was constructed for each of the six footprints that were obtained. A production schedule enables the calculation of the free cash flow which can be recalculated to a net present value (NPV) that provides a common platform to compare the different footprints. Two scenarios were tested in the financial model. The first scenario's variable costs were based on the variable costs that were used to determine each of the VDMs and the second scenario's costs were based, entirely, on TDABC. Therefore, twelve NPVs were obtained. In all twelve NPVs that were calculated the order of the NPVs were the reverse of the order of the discounted variable costs (DVCs); in other words a high DVC yielded a low NPV and vice versa. The results showed no correlation between the NPVs of Scenario 01 and Scenario 02.

It is recommended that TDABC be applied to determine the variable costs during the resource optimisation phase. Together with this it is also recommended that various cut-off values are applied during the optimisation phase so that multiple footprints' NPVs can be obtained so that the most valuable footprint will come to the fore.

Keywords: Activity-based Costing, Time-driven Activity-based Costing, Mining Resource Optimisation

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LIST OF SYMBOLS AND ABBREVIATIONS

$/m^3$	Dollar per cubic metre
$/t	Dollar per tonne
%	Percent or percentage
ABC	Activity-based costing
CAPEX	Capital expenditure
COG	Cut-off grade
DFCF	Discounted free cash flow
DMR	Department of Mineral Resources
DVC	Discounted variable cost
GDP	Gross domestic product
GFCF	Gross fixed capital formation
GTIS	Gross tonnes in situ
LG	Lerchs-Grossman three-dimensional graph theory
LOM	Life of mine
LTP	Long term planning
M	Metric metre
Mt	Million tonnes
MTIS	Mining tonnes in situ
NPV	Net present value
O&M	Operational and maintenance cost
OEM	Original equipment manufacturer
OPEX	Operating expenditure
PC	Process costing
PGM	Platinum group metals
prodt	Product tonnes
R/l	Rand per litre
ROM	Run of mine
ROMt	Run of mine tonnes
SIB	Stay in business
T	Metric tonne
TDABC	Time-driven activity-based costing
VDM	Value distribution model

CHAPTER 1: INTRODUCTION

1.1 Background

South Africa (SA) has vast mineral resources; the bulk of these resources are in the following geological structures and settings (SAMI, 2015:9):

- The Witwatersrand Basin yields approximately 93% of SA's gold output; apart from gold, the resource is also rich in uranium, silver, pyrite and osmiridium.
- The Bushveld Complex is rich with the platinum group metals (PGMs), chromium and vanadium rich titanium iron ore and industrial minerals such as fluorspar and andalusite.
- The Transvaal Supergroup contains resources rich in manganese and iron ore.
- The Karoo Basin is the host of bituminous coal, anthracite and shale gas.
- The Palaborwa Igneous Complexes are rich in copper, phosphate, titanium, vermiculite, feldspar and zirconium.
- The Kimberlite pipes host diamonds; diamonds are also found in alluvial, fluvial and marine settings.
- Heavy mineral sands contain ilminite, rutile and zircon.
- The Northern Cape close to Aggeneys has lead-zinc ores that are associated with copper and silver.

It is thought that there could be significant undiscovered resources; most of the current resources were discovered by, now obsolete, exploration techniques (SAMI, 2015:9). SA is no longer among the top ten African countries where large exploration spending is taking place, but it is still counted amongst the major African countries where exploration is being done (SAMI, 2015:13). In 2012 the Department of Mineral Resources (DMR) received 2,705 applications for prospecting rights and 144 for mining rights. The applications mostly targeted Platinum Group Metals (PGMs), diamonds, uranium and coal (SAMI, 2015:14).

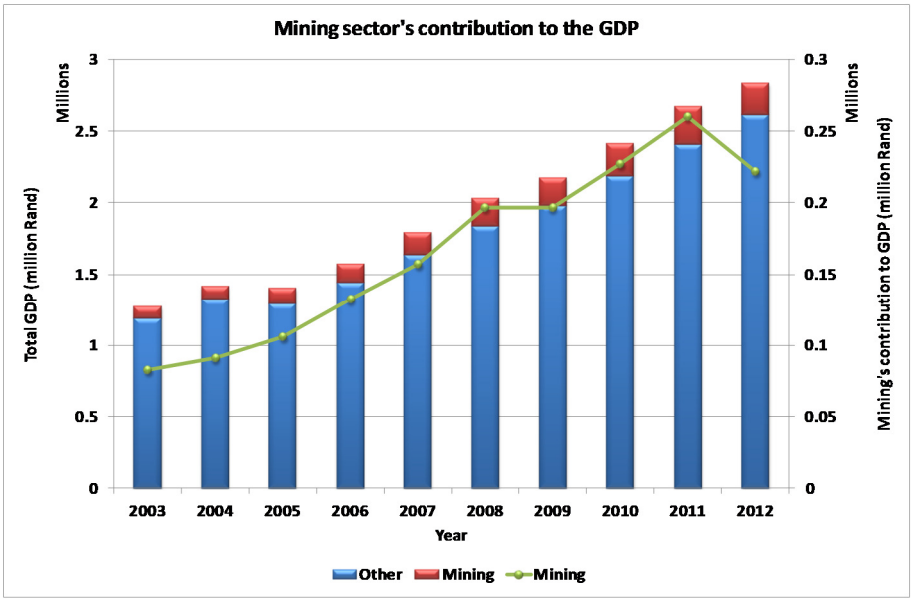
1.2 Field of research

The SA mining industry is a key economic sector that can contribute to economic growth, job creation and transformation that compliments the government's objectives of higher and more balanced economic growth. In 2012 the mining sector contributed R221.7 billion, i.e. 9.3% of the gross domestic product (GDP). In 2011 the mining sector's contribution was R183 billion. The R38.7 billion increase in 2012 can be attributed to (SAMI, 2015:14):

- The rand/dollar exchange rate.
- Increase in the gold price.

- Increase in the production of ferrous minerals.

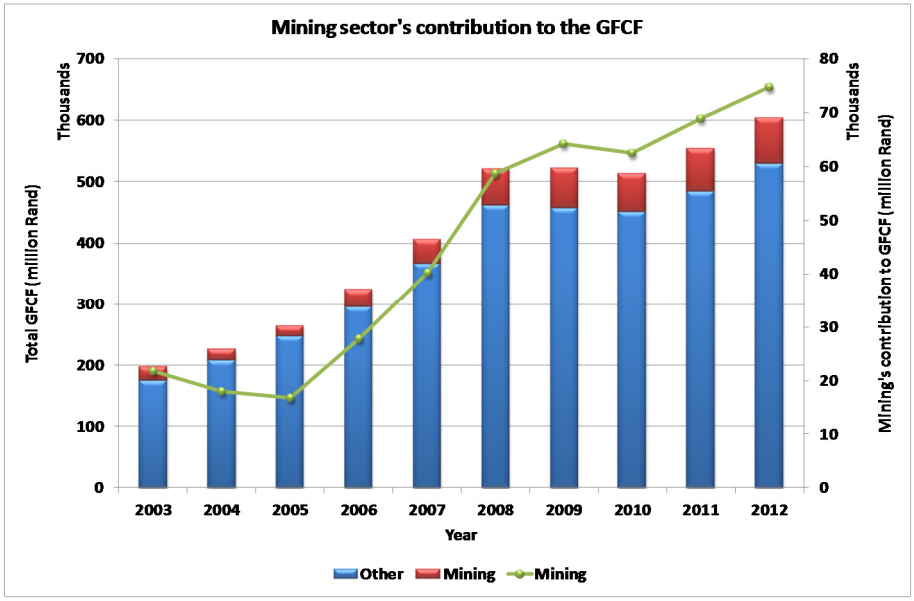
The mining sector continues to show an upward trend in its contribution to the gross domestic product (GDP), gross fixed capital formation (GFCF) and exports; refer to Figure 1-1, Figure 1-2 and Figure 1-3 respectively (SAMI, 2015:15).



Source: (Modified) SAMI, 2015:15.

Figure 1-1: Mining sector's contribution to the GDP

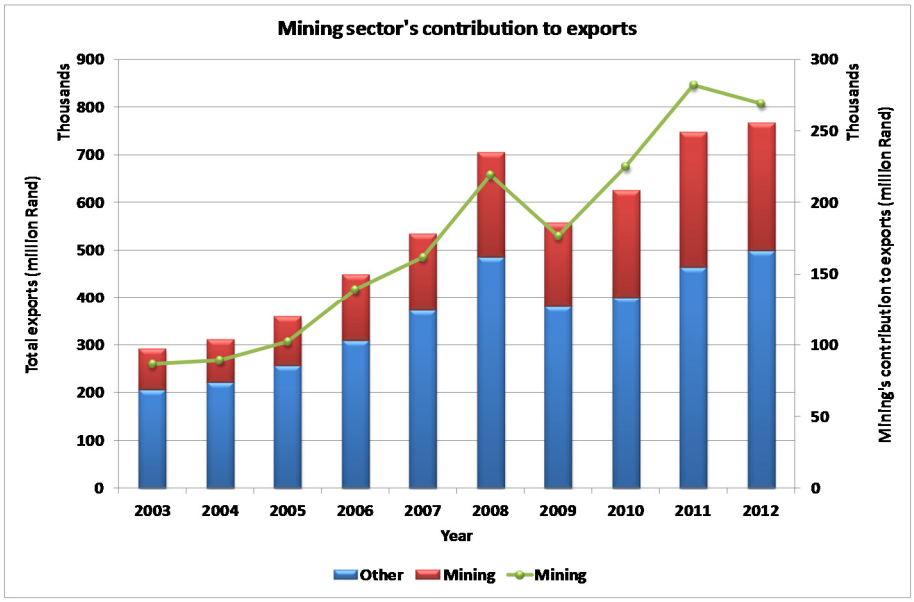
Figure 1-1 shows the growing contribution that mining is making towards the GDP. However, a significant drop in mining's contribution to the GDP from 2011 to 2012 is evident; this is because the industry was severely affected by the unprotected strikes (SAMI, 2015:15).



Source: (Modified) SAMI, 2015:15.

Figure 1-2: Mining sector's contribution to the GFCF

The mining sector's contribution to the GFCF shows an upward trend and increased from R68,800 million in 2011 to R74,658 million in 2012 (refer to Figure 1-2).



Source: (Modified) SAMI, 2015:15.

Figure 1-3: Mining sector's contribution to exports

Figure 1-3 shows that mining's contribution to exports shows an upward trend with a slight decline in contribution from 2011 (R282,012 million) to 2012 (R269,119 million). Furthermore, in line

herewith, the mining industry employed 2.9% (excluding exploration, research and development and head offices) of the economically active SA population in 2012 or 2.6% of all workers in the non-agricultural formal sectors of the economy (SAMI, 2015:17).

Table 1-1: Newly committed mineral-related projects in SA, 2012

	Cost (R million)	% of primary	% of total
Primary minerals	147,237	100	88
Gold	8,005	5	5
Platinum	80,785	55	48
Other	58,447	40	35
Processed minerals	20,000		12
Total	167,237		100

Source: (Modified) SAMI, 2015:25.

Newly committed investment to mineral related projects in SA was R167,237 million in September 2012 (88% for primary minerals and 12% for processed mineral products). Platinum projects accounted for 55%, other minerals for 40% and gold for 5% of the September 2012 committed investment (refer to Table 1-1) (SAMI, 2015:24).

1.3 The costing dilemma in the mining industry

One of the biggest risks to a mining project is the unknown of the geology. Geostatistical methods are used to estimate the geology for the construction of a geological model. The geological model is converted to a mining model by applying the relevant modifying factors such as the geological losses, mining losses and recoveries. In essence, the mining model is what the mining engineer deems mineable. These factors sprout from best practices, historical data and knowledge of the ore body itself.

After the mining model has been finalised, the optimisation process commences. During optimisation costs and prices are applied to the ore body to determine the portions of the ore that are deemed economical for exploitation. All the references found to the capital and operating expense inputs to the optimisation process refer to benchmarked unit costs, i.e. Rand per tonne (Dimitrakopoulos *et al*., 2007:77; Whittle & Bozorgebrahimi, 2004:403; Whittle *et al*., 2007:5; Richmond, 2011:229-231; Elkington & Durham, 2011:184; Frimpong & Achireko, 1997:49). Unit costs could be a suboptimal and possibly flawed, input to the optimisation process.

The researcher believes that the current optimisation practices could be suboptimal, because the application of unit costs will over-penalise “good” reserves and under-penalise “bad” reserves. A unit cost that is applied will typically sprout from historical data on the mine or a similar mine. Such a cost will be a back calculation from actual data. For example, the total expenditure, both fixed

and variable, will be accumulated and divided by the ore tonnes mined for that period which yields a unit cost (Rand/tonne). If this unit cost is applied to the budget forecast of the mine or used to optimise another mine's resources, the resultant value could be an over- or under-estimation of the true value. Why? Because, inevitably, the geology will vary, which will result in fluctuations in the variable costs. No one year has the same production volumes, assuming that the fixed costs remain constant year-on-year; the fixed costs' unit cost will be different.

The proposed cost application method, which will be investigated in this study, is Time-driven Activity-based Costing (TDABC). TDABC will apply the operating cost or running cost (Rand/hour) and productivity (tonne/hour, metre/hour, cubic metre/hour, etc.) of equipment (haul trucks, excavators, drill machines, etc.) to derive the unit cost (Rand/tonne, Rand/metre, Rand/cubic metre, etc.). These unit costs will be determined for the different geological areas, i.e. for each location where the geology varies, the unit cost applied to the ore and waste to be mined in that area will be unique. The fixed costs as a unit cost can only be calculated from the production schedule that follows the optimisation phase; therefore, fixed costs will be excluded from the optimisation phase.

1.4 Cost accounting methodologies available to the mining industry

Traditional accounting systems are accounting systems that meet the requirements of investors, lenders and income tax authorities. The traditional accounting system is based on absorption costing; absorption costing is aptly named for the manner in which inventory is shown on the balance sheet and cost of goods sold is shown on the income statement. Therefore, absorption costing is the manner in which products "absorb" costs as it is manufactured. Absorption costing makes the assumption that, when a product is manufactured it "absorbs" the expenses that are necessary for the product to be manufactured: direct materials which it is made up of; labour used during manufacturing; overhead costs that are applicable (depreciation of machinery and facilities, supervisory costs, heat and electricity and other costs related to operating the firm) (Baxendale, 2001:61).

Baxendale (2001:62) explains that absorption costing causes a distortion due to the manner in which manufacturing overheads are reflected on the product. Factory overheads are not like direct material costs that vary with direct proportion to the number of units manufactured; factory overheads are usually fixed costs. This means that, if the production volume declines in a period, the overheads will most likely not lower proportionally. The inclusion of direct costs and fixed costs causes a costing distortion that could, potentially, be misleading. Lind (2001:77) refers to absorption costing in the mining industry as process costing. Lind argues that there are two ways in which mining systems are costed; the current method (process costing) and the way that it could be costed. It is therefore important to review the way in which mining systems are currently

costed. The current method could, potentially, be flawed, leading to detrimental impacts on the budget and could even cause the wrong decision to be made with a marginal project that will lead to losses. Lind proposes a costing method that incorporates elements of different modern costing techniques; given that there is no one technique that is the best. The major shortcomings of the traditional costing methods are summarised as (Lind, 2001:78):

- Cross-subsidisation of costs.
- Cost of technology (capital) is treated as a period cost.
- Processes rather than specific groups of products are costed.
- Difficult to account for multiple products.

Baxendale (2001:63) states that the trend is moving away from labour intensity and moving towards capital intensity (automation, technology and computerisation). This has lowered the production costs of products; the result is that a larger proportion of the product costs are fixed. Also, marketing and distribution costs are playing a more significant role in getting a product to a point of consumption. Baxendale states that activity-based costing (ABC) supplements the absorption costing method. ABC aids in the preparation of accounting information to be used in tactical and strategic planning. Similarly Lind (2001:79) identified that ABC is more effective in obtaining operating costs than traditional costing methods. The difference between ABC and traditional costing techniques is in how ABC treats non-volume related overhead costs. Mining resource optimisation is a tactical and strategic function that mining houses carry out to aid the decision process for future capital investments; operating and overhead costs play significant roles in mining resource optimisation.

ABC is a more detailed approach to determining the cost of goods and services. The costing accuracy is improved by emphasising the cost of activities or tasks that is conducted to produce a product or offer a service. ABC is a functional based overhead costing system that has two major stages (Mowen *et al.*, 2014:259):

- The overhead costs are assigned to an organisational unit (plant or department).
- Overhead costs are then assigned to cost objects.

The assumption of ABC is that activities consume resources and cost objects consume activities. ABC places emphasis on direct tracing and driver tracing and by doing so, cause-and-effect relationships are exploited. Therefore, ABC requires (Mowen *et al.*, 2014:259):

- The tracing of costs to activities.
- Tracing the activity costs to cost objects.

This leaves the question of whether the current practice, of using unit costs for capital expenditure (CAPEX) and operating expenditure (OPEX) during resource optimisation in mining projects, is optimal.

1.5 Research problem and objectives

In context of the above, it is seen that costs calculated by TDABC will assign different unit costs as the mining conditions vary. In light hereof, the ***primary research problem*** to be considered in this study is whether TDABC application of variable costs, during the resource optimisation phase, provides significantly different results than the current practice of applying benchmarked unit costs.

In answering, the primary objective of this study is to determine the effect of applying TDABC for the variable costs, as opposed to benchmarked unit costs, during the resource optimisation phase, on the net present value (NPV) of a mining project.

In support of the primary objective, the specific objectives of this study are identified as follows:

- To define a hypothetical ore deposit that will form the basis of the case study; the geological to mining model conversion should be conducted on this deposit to ready the model for the resource optimisation process.
- Resource optimisation: to determine the economical footprint(s) of the resource by constructing a value distribution model(s) with different variable cost inputs.
- To estimate the NPV of each of the economical footprint(s), for comparison purposes, by means of a financial model.

1.6 Method of research

1.6.1 Research design

Welman *et al*. (2011:6-7) states that there are two main approaches to research: quantitative and qualitative. Trochim and Donnelly (2007:11) explain the difference between quantitative and qualitative data in a simple manner: typically data is quantitative if it is numerical and qualitative if it is not. This study will be quantitative.

1.6.2 Research methodology

USC Libraries (2014) states that a case study is an in-depth study of a particular research problem instead of a statistical survey or comprehensive comparative inquiry. Case studies are often used to narrow down a very broad field of research into one or a few easily researchable examples. The case study research design is also useful for testing whether a specific theory and model

actually apply to phenomena in the real world. It is a useful design when not much is known about an issue or phenomenon. The research method for this study is a case study substantiated by a literature and empirical study.

1.6.3 Literature review

A literature review is necessary to ensure that the researcher is acquainted with previous research that has been conducted on the topic. By conducting the literature review the researcher will prevent doing research on a topic on which a general consensus has been reached (Welman *et al.*, 2011:38). Relevant literature for this study will be obtained from journals, books, conferences and the internet.

1.6.4 Measuring instrument

Due to the nature of the study, the following will apply:

- The use of secondary data as the data will not be collected (survey data), instead it will be sourced.
- The measuring instrument is classified as an "indicator". NPV (dependent variable) will be used as an indicator of the influence that the independent variables have.
- The use of unobtrusive measurement, specifically official statistics and archives: benchmark data from previous projects and existing operations and original equipment manufacturer (OEM) data.

1.6.5 Research procedure

The focus of this study will be to compare benchmarked unit costs and calculating costs by applying TDABC when a mining resource is optimised. Therefore two streams of data will be required: benchmark / historical data and original equipment manufacturer (OEM) data. The bottom line will be the difference in NPV between the two methods of applying costs.

- **Step 01**: A commodity and a mining method must be chosen.
- **Step 02**: A resource (ore deposit) has to be obtained / chosen / manufactured that will be used for the study.
- **Step 03**: It should be determined which cost pools will be applied during the study. The focus will be on "big ticket items" that contribute the bulk (±80%) of the expenditure. Items that will typically, be included are: in-pit / underground mining costs; equipment costs (purchase and maintenance); overheads (labour complement) and processing costs.
- **Step 04**: Based on the commodity and mining method, relevant data will be collected (benchmark and OEM data).

- **Step 05**: An extensive literature search will be conducted to identify the methods that have been used for cost application during resource optimisation.

1.7 Terminology

For the purposes of this study the following are taken as applicable / relevant definitions:

- **Activity cost pool**: A grouping of individual costs that are associated with a business activity (Accounting Tools, 2015; Houston Chronicle, 2015).
- **Activity dictionary**: Lists the activities performed by an organisation along with some critical activity attributes (Mowen *et al*., 2014:261; Hilton *et al*., 2008:147).
- **Activity**: An activity is a discrete task that an organisation undertakes to make or deliver a good or service (Hilton *et al*., 2008:53&147).
- **Block model**: A three-dimensional array of blocks that covers the entire ore body and sufficient surrounding waste to allow access to the deepest ore blocks (Khalokakaie *et al*., 2000:77).
- **Burn rate**: For this study the burn rate is the rate at which equipment / machinery consumes diesel / petrol expressed in litres per hour (l/h) (Own definition).
- **Capital expenditure (CAPEX)**: Funds used by a company to acquire or upgrade physical long term assets such as property, industrial buildings or equipment. The cost (except for the cost of land) will then be charged to depreciation expense over the useful life of the asset (Investopedia, 2014; Accounting Coach, 2015).
- **Coal seam**: Laterally continuous layer of coal, with or without included non-coal bands, which forms a coherent and distinct geological stratigraphic unit (SANS, 2004:10).
- **Contamination**: Extraneous coal and non-coal material unintentionally added to the practical mining horizon as a result of mining operations (SANS, 2004:36).
- **Cost behaviour**: A term that describes whether a cost changes when the level of activity changes (Mowen *et al*., 2014:62; Hilton *et al*., 2008:54; Garrison *et al*., 2010:46).
- **Cost driver**: Causal factor that measures the output of the activity that leads (or causes) costs to change (Mowen *et al*., 2014:62).
- **Discard**: Discards and reject coal produced as part of production from a coal processing plant (SANS, 2004:36).
- **Fixed cost**: A cost that does not change, for a specified time period, if the output / activity volume changes (Mowen *et al*., 2014:62; Hilton *et al*., 2008:54; Garrison *et al*., 2010:49).
- **Free-digging**: For this study free-digging refers to material that does not require drilling and blasting so that equipment can remove the material from the solid surface (Own definition).

- **Geological loss**: Discount factor applied in the case of gross in situ tonnage to account for as yet unobserved geological features that can occur between points of observation (SANS, 2004:21).
- **Geological model**: Three-dimensional geological computer model containing volumetric estimates and coal quality estimates (SANS, 2004:21). Also refer to "**Block model**".
- **Graben**: A portion of the earth's crust, bounded on at least two sides by faults, that has dropped downward in relation to adjacent portions (Dictionary.com, 2015).
- **Gross tonnes in situ**: Tonnage and coal quality, at specified moisture content, contained in the full coal seam above the minimum thickness cut-off and relevant coal quality cut-off parameters, as defined by the competent person (SANS, 2004:23).
- **In situ**: In the original place (Oxford dictionaries, 2015).
- **Metallurgical recoveries**: The percentage of metal contained in ore that can be extracted by processing (InsideMetals, 2015).
- **Mining face**: Any place in a mine where material is extracted during a mining cycle (CaseyResearch, 2015).
- **Mining loss**: Mining layout loss, mining layout extraction loss, mining recovery efficiency factor (SANS, 2004:27).
- **Mining model**: For this study a mining model is a geological model to which the appropriate modifying factors have been applied so that the run of mine tonnes and qualities are contained as attributes in the model (Own definition).
- **Mining tonnes in situ**: Tonnage and coal quality, at a specified moisture content, contained in the coal seams or sections of the seams, which are proposed to be mined at the theoretical mining height, excluding dilution and contamination material, with a specific mining method and after the relevant minimum and maximum mineable thickness cut-off and relevant coal quality cut-off parameters have been applied (SANS, 2004:24).
- **Modifying factor**: Realistically assumed mining, geotechnical, coal quality, coal processing, economic, marketing, legal, environmental, social and governmental factors (SANS, 2004:24).
- **Net present value**: The difference between the present value of cash inflows and the present value of cash outflows. The net present value of the expected cash flows is computed by discounting them at the required rate of return. NPV is used in capital budgeting to analyse the profitability of an investment or project (Investopedia, 2014; Business Dictionary, 2015).
- **Operating expenditure**: A category of expenditure that a business incurs as a result of performing its main operating activities (normal business operations) (Investopedia, 2014; Accounting Coach, 2015).

- **Optimiser**: For this study an optimiser is an optimisation software program such as Geovia's Whittle (Own definition).
- **Overburden**: Material overlying a deposit of useful geological materials or bedrock (Merriam-Webster, 2015).
- **Period progress plot**: For this study a period progress plot is a graphic that shows the sequence of extraction, in time, of the ore body that is simulated by the production schedule (Own definition).
- **Pit shell**: Pit shell is the mining outline of an open pit that maximises undiscounted cash flows for a given set of slope constraints, revenues and cost parameters (Elkington & Durham, 2011:178).
- **Primary plant efficiency**: For this study the primary plant efficiency is a coal processing modifying factor (Own definition).
- **Production schedule**: For this study a production schedule is a simulation of the extraction sequence of the blocks in a block model (Own definition).
- **Resource driver**: Factors that measure the consumption of resources by activities (Mowen *et al*., 2014:261).
- **Resource optimisation**: A process to find the optimal pit outline that maximises the dollar value, for a given input ore body model and a given set of economic and geotechnical conditions (Whittle & Bozorgebrahimi, 2004:399).
- **Revenue factor**: For this study the revenue factor is the factor by which the commodity price is multiplied during the optimisation process (Own definition).
- **Roll-over dozing**: For this study roll-over dozing is strip mining where the overburden is removed by dozers (Own definition).
- **Secondary plant efficiency**: For this study the secondary plant efficiency is a coal processing modifying factor (Own definition).
- **Strip mining**: The removal of soil and rock (overburden) above a layer or seam (particularly coal), followed by the removal of the exposed mineral (Encyclopaedia Britannica, 2015).
- **Strip ratio**: Ratio of overburden volume to coal tonnes in the mineable coal seam (on an in situ, run of mine or sales tonnage basis), typically in opencast mineable areas and measured in bank cubic metres/tonne (bcm/t) (SANS, 2004:30).
- **Tabular deposit**: A flat table like or stratified bed e.g., a coal seam (Mindat.org, 2015).
- **Variable cost**: A cost that changes (or varies) in direct proportion as the output / activity volume varies (Mowen *et al*., 2014:62; Hilton *et al*., 2008:54; Garrison *et al*., 2010:48).

1.8 Chapter overview

The mini-dissertation consists of the following chapters:

1.8.1 Chapter 1 – Introduction

This chapter consists of the background to the study, the field of research, the costing dilemma in the mining industry, cost accounting methodologies available to the mining industry, research problem and objectives, method of investigation and research, terminology and the chapter overview.

1.8.2 Chapter 2 – Costing methodologies used and available to the mining industry

This chapter contains a thorough literature survey of how costs are being applied during the optimisation phase of a mining resource. The alternative costing methods that are available and applicable to the resource optimisation phase, of a mining project, are investigated and documented.

1.8.3 Chapter 3 – Mining resource optimisation case study

In this chapter a fictive resource has been optimised using the different cost application methods identified in the literature survey as well as the proposed TDABC method. A high level cash flow of each of the optimisations has been used to calculate an NPV for each of the cost application methodologies; the NPV makes it possible to quantify the variance in value.

1.8.4 Chapter 4 – Conclusion and recommendations

Based on the findings of the case study, recommendations have been made on the accuracy of the results of the different costing methods. A best practice is identified and recommendations for further studies are made.

CHAPTER 2: COSTING METHODOLOGIES USED AND AVAILABLE TO THE MINING INDUSTRY

2.1 Introduction

There is a need for organisations to understand their costs and what drives those costs, but many organisations are confused about their costs and struggle to choose between the different cost measurement methodologies. The answer could, possibly, not lie with a single costing method but rather a blend of the available methods. Costing techniques can be married because all of the methods have a single goal – an estimation of the consumption of economic resources (Cokins, 2001:73).

The previous chapter provided an overview of the SA mining industry and showed that the industry significantly contributes to the GDP, GFCF and exports. It was highlighted that industries are moving away from being labour intensive to being more capital intensive which amplifies the costing challenge experienced when a mining resource is being optimised. Current practice sees the use of unit costs (R/t), obtained from benchmarked / historical data, being applied. The chapter stated that TDABC could be a more optimal cost application method when resources are being optimised. The chapter further stated the research problem and objectives, the method of research and the research procedure that will be followed. Finally, a chapter overview was provided.

This chapter firstly focuses on ABC; ABC will form the basis of the costing technique used for resource optimisation. The possibility does exist that the costing technique will be a hybrid of methods, but it is foreseen that for the biggest part ABC will be applied. Secondly the chapter aims at providing insight into mining resource optimisation: a background is provided, the principles of mining resource optimisation are discussed, the typical project optimisation process is reviewed, the typical characteristics of an optimised LOM plan is discussed, a view is taken of the prevailing cost application technique, an alternative cost application method for mining resource optimisation is proposed and an example of how costs for a mining project could be calculated is provided.

2.2 Activity-Based Costing

2.2.1 Background

There is a growing need for more accurate product costing which is forcing companies to review and reconsider the costing techniques they employ. Traditional costing methods (plantwide and departmental rates) based on direct labour hours, machine hours or other volume-based

measures can be used to assign overhead costs to products. These methods can have the same effect as averaging the costs and can result in distorted and inaccurate costing – overstating and understating costs. Companies that have a large proportion non-unit-related overhead cost to total overhead cost and / or high product diversity should consider venturing beyond traditional costing techniques (Mowen *et al*., 2014:250).

ABC was originally introduced by Robin Cooper and Robert Kaplan in the late 1980s. ABC is a managerial costing tool – it connects resource costs with activities. The costs can then be assigned to cost objects (products, services, customers, etc.) in the proportion that the cost object used the activities. Because ABC is more expensive and not required for external financial reporting it should only be implemented if the expected benefit outweighs the cost thereof (Kennett *et al*., 2007:20). The complexity and costliness of ABC has raised the question: Is ABC still relevant?

Stratton *et al*. (2009:31) states that ABC was very popular in the 1990s but that there have been debates since regarding the overall relevance of the costing method. They conducted a survey of the importance of ABC (348 manufacturing and service companies worldwide). The survey concluded that, from a strategic and operational perspective, ABC still offers organisations significant value. Stratton *et al*. (2009:37) posed the following statement in a survey: "Our costing system supports decision making and is integrated with budgeting and planning." On a Likert Scale of 0 to 6 (0 = strongly disagree; 6 = strongly agree) the companies rated how their costing system supports the following:

- Financial decisions
- Operational decisions
- Strategic decisions
- Integrated with budgeting and planning processes

In all of the above cases ABC rated higher than the other costing methods.

Stratton *et al*. (2009:38-39) summarised their findings regarding ABC as follows:

- ABC is employed across the entire internal value chain and the majority of organisations continue to use it.
- ABC addresses the need for accurate overhead allocation.
- ABC eases concerns regarding the: accuracy of cost allocations; cause effect relationship between allocations and resources consumed; timeliness of cost / profit information and the ability to update systems.
- ABC gives better support for financial, operational and strategic decisions.

- ABC can be better integrated into budget and planning processes.

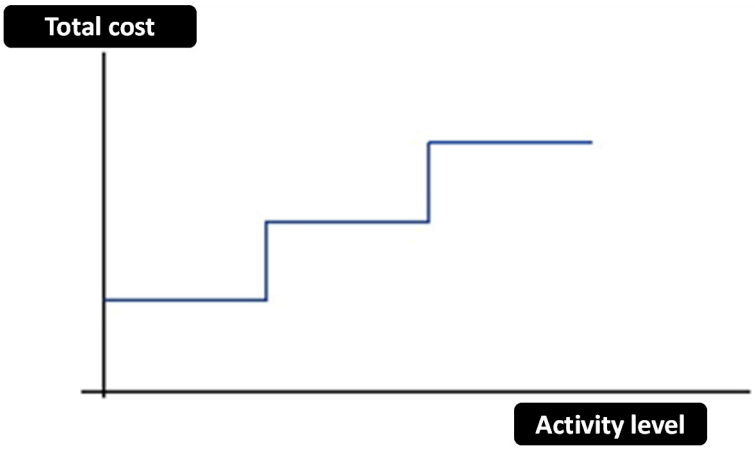
When referring to resource optimisation and long term planning (LTP) the costing method used should support:

- Financial decisions – Do we or do we not invest in the mine?
- Operational decisions – Where should the mine be exploited first? Do we extend the LOM?
- Strategic decisions – Can we provide the market with the required qualities and quantities of the commodity?
- Budgeting and planning processes – resource optimisation and LOM planning has a direct impact on the budgeting of a mine (equipment requirements, labour complement, CAPEX, OPEX, etc.).

From the above it seems that ABC could be the better costing method for resource optimisation.

2.2.2 Cost behaviour

Cost behaviour is a term that describes whether a cost changes when the level of activity changes (Mowen *et al.*, 2014:62; Hilton *et al.*, 2008:54; Garrison *et al.*, 2010:46). An activity is a discrete task that an organisation undertakes to make or deliver a good or service (Hilton *et al.*, 2008:53&147). This gives rise to the terms fixed cost and variable cost. A fixed cost is a cost that does not change if the output / activity volume changes (Mowen *et al.*, 2014:62; Hilton *et al.*, 2008:54; Garrison *et al.*, 2010:48-49; Drury, 2008:32). Although, in practice, it is not likely that a cost will remain constant over a full range of activity; the fixed costs may increase in steps with an increase in activity level as depicted in Figure 2-1 (Drury, 2008:32).



Source: OpenTuition.com, 2015.

Figure 2-1: Step fixed cost

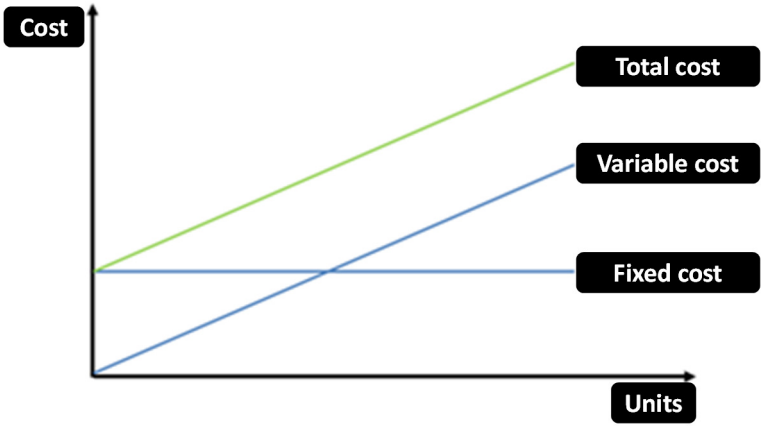
A variable cost changes (or varies) in direct proportion as the output / activity volume varies. A variable cost will increase in value as the total output increases and vice versa; if the level of activity doubles, the variable cost doubles and when the level of activity halves, the variable cost will half (Mowen *et al*., 2014:62; Hilton *et al*., 2008:54; Garrison *et al*., 2010:48-49; Drury, 2008:32). The equation below illustrates how a variable cost behaves (Mowen *et al*., 2014:66):

$$Total\ variable\ costs = variable\ rate\ \times\ units\ of\ output$$

For example:

$$Total\ variable\ costs = R400\ \times\ number\ of\ computers$$

Figure 2-2 shows the relationship between total, variable, and fixed costs. The fixed cost remains constant regardless of the units of output. The fixed cost curve is a horizontal line that intersects the cost axis at the value of the fixed cost. The variable cost curve starts at the origin, i.e. at cost equal zero and units equal zero. The variable costs changes for each additional unit produced, however, the per unit cost remains constant. The total cost is a summation of the fixed and variable cost curve at any given unit of output.



Source: PrepLounge, 2015.

Figure 2-2: Total cost vs variable cost vs fixed cost

To classify a cost as fixed or variable, the behaviour of the cost should be understood. To understand the behaviour of the cost the measure of the output associated with the activity should be understood, i.e. the way the cost changes in relation to changes in the organisation's activity (Mowen *et al*., 2014:62; Hilton *et al*., 2008:53). A cost can only be classified as fixed or variable when it is related to a measure of output, therefore a cost is either fixed or variable with respect to a measure of output or a driver. The underlying business activity has to be identified and it has to be determined what causes the activity to increase or decrease (Mowen *et al*., 2014:62). Mowen *et al*. (2014:62) states that the cost driver can be defined as a "causal factor that measures the output of the activity that leads (or causes) costs to change." Because of the causal effect managers can manage costs by managing the drivers. The causal effect of a driver on an activity is better understood by means of the examples depicted in Table 2-1:

Table 2-1: Activity vs driver

Activity	Driver	Driver quantity
Setting up equipment	Setup hours	4
Moving goods	Number of moves	10
Machining	Machine hours	50
Assembly	Direct labour hours	100

Source: Mowen *et al*., 2014:255.

Table 2-1 lists four business activities, each with a cost driver that is the causal factor that measures the output of the activity that causes a change in the cost. For instance, the cost of setting up equipment can be managed by reducing the setup hours reflected in the "driver quantity" column.

2.2.3 Cost hierarchy

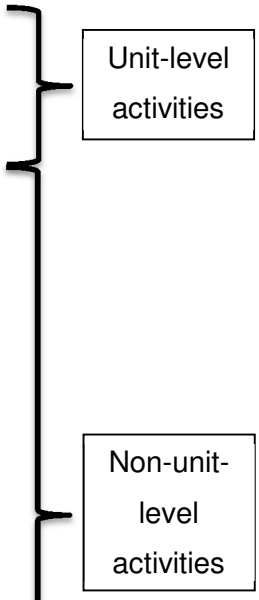
The use of plantwide rates or departmental rates that are based on direct labour hours, machine hours or other volume-based measures makes the assumption that the product consumes costs at a rate that is directly proportional to the number of units produced. This assumption is only correct for unit-level activities (refer to Table 2-2) because the activity is performed for every unit of the product that is produced (Mowen *et al*., 2014:250-251; Hilton *et al*., 2008:55). These costs are variable costs because the variance in the cost is directly related to the volume of units produced. Any other costs (costs that are non-unit level) are considered as fixed costs by volume-based cost systems (Mowen *et al*., 2014:250). Non-unit-level activities have costs that are unlikely to vary with the volume of units that are produced; therefore, other factors are responsible for a variance in these costs (Mowen *et al*., 2014:250-251; Hilton *et al*., 2008:55). The activities associated with these costs are non-unit-level activities, i.e. the activities are not performed each time a unit or product is produced. This gives rise to the ABC cost hierarchy. The hierarchy can have many levels; a simple hierarchy categorises costs as (Mowen *et al*., 2014:250-251; Hilton *et al*., 2008:55; Drury, 2008:230-231):

- Unit level: varies with output volume i.e. incurred for every unit of a product or service produced.
- Batch level: varies with the number of batches produced.
- Product sustaining: varies with the number of product lines.
- Customer level: incurred for specific customers.
- Facility sustaining: necessary to operate the plant facility but does not vary with units.

Table 2-2 shows the ABC cost hierarchy with an example of each (Mowen *et al*., 2014:250-251; Hilton *et al*., 2008:55).

Table 2-2: ABC Hierarchy

Type of Cost	Description of Cost Driver	Example
Unit level	Varies with output volume (e.g. units); traditional variable costs	Cost of indirect materials for labelling each bottle of perfume
Batch level	Varies with the number of batches produced	Cost of setting up laser engraving equipment for each batch of key chains
Product sustaining	Varies with the number of product lines	Cost of inventory handling and warranty servicing of different brands carried by an electronics store
Customer level	Incurred for specific customers	Costs for licensing of university logos sewn onto some shirts produced
Facility sustaining	Necessary to operate the plant facility but does not vary with units, batches or product lines	Cost of a plant manager's salary



Source: Mowen *et al*., 2014:251; Hilton *et al*., 2008:55.

Typical examples of the ABC hierarchy items for a mining project would be:

- The operator as a unit-level cost – the salary of the operator is assigned directly to the operating overheads of the haul truck.
- The excavator (loading equipment) operator as a batch-level cost – for each excavator there are a couple of trucks, so the costs need to be split across all the trucks in that working face.
- The pit supervisor will be a product-sustaining cost – this person is responsible for a number of working faces.
- The mine manager is a typical facility-sustaining cost – his / her costs need to be spread across all the activities, including the mining, processing and selling of the product.

This leaves the question: "What measures the consumption of non-unit-level activities?" The answer is that non-unit-level activity drivers (batch, product and facility sustaining) measure the consumption of non-unit-level activities by products and other cost objects. The caution lies in the fact that when unit-level activity drivers are used to assign costs that are not unit related, the costs

of a product can be distorted. The solution lies in being careful when assigning costs. The severity of the distortion of the product cost depends on the proportion of the non-unit-related costs to the unit-related costs. The greater the proportion the more the costs will be distorted. The smaller the proportion the more acceptable it will become to use unit-based activity drivers to assign the non-unit-related costs. It should be noted that the presence of non-unit-level costs does not necessarily mean that costs will be distorted when unit-level activity drivers are used to drive the costs. It could be that the non-unit-level activities are consumed in the same proportion as the unit-level activities; then no distortion will occur. For distortion to occur, product diversity is required. With product diversity it is meant that products consume activities in different proportions; the reason for the different consumption proportions can happen for many reasons, some of which are differences in (Mowen *et al*., 2014:252):

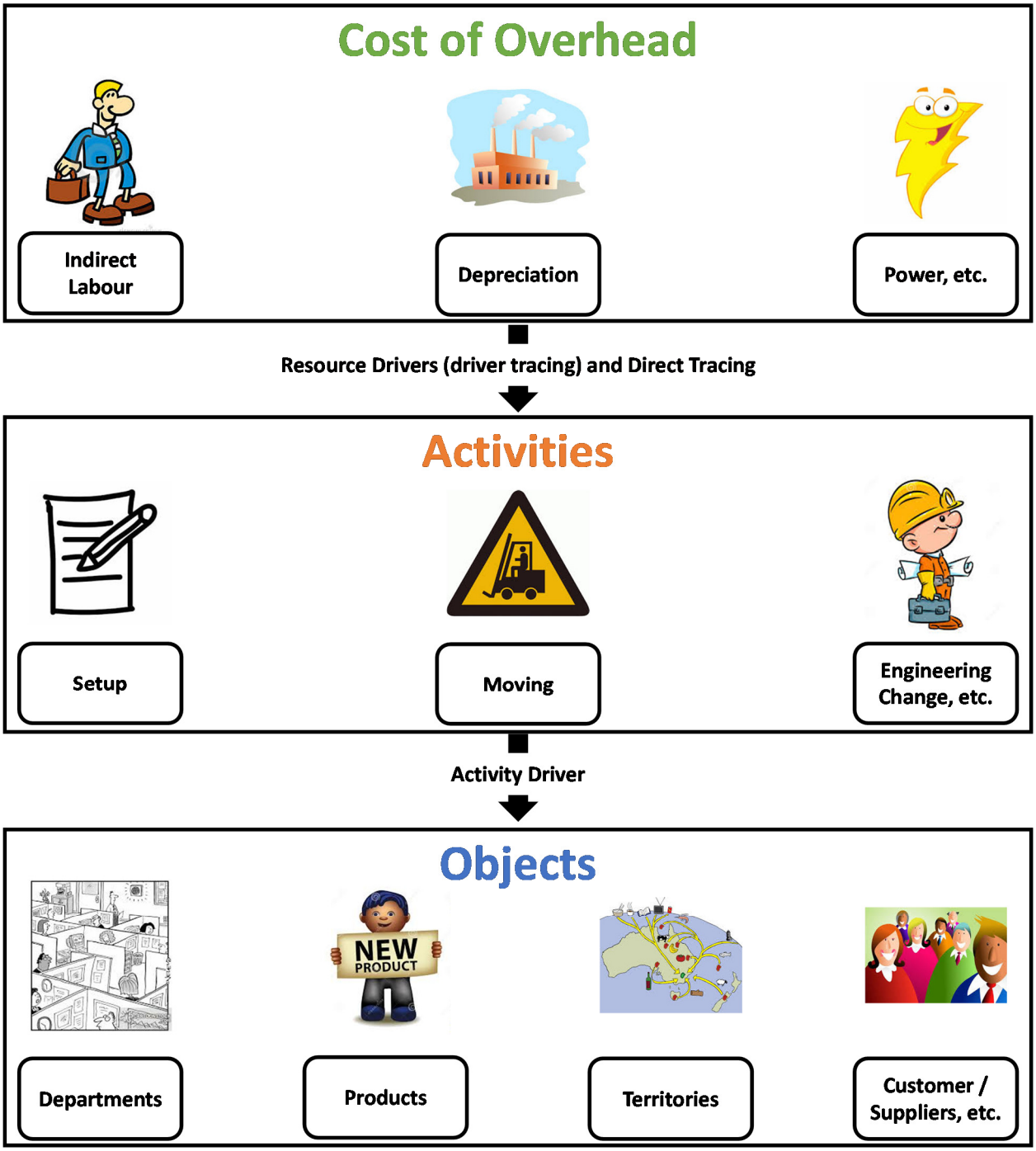
- Product size
- Product complexity
- Setup time
- Size of batches

2.2.4 Activity-Based product costing

ABC is a costing method that first assigns costs to activities and then to goods and services, proportional to how much the activities are used by each of the goods and services. As mentioned in Section 2.2.2 – *Cost behaviour*, an activity, is a discrete task that an organisation undertakes to make or deliver a good or service. Therefore, the only manner in which managers can manage costs is by modifying the activities used to produce the service or product. The sole purpose of ABC is to assist managerial decision making, like, whether a certain product line should carry on being produced or halted. ABC is not for inventory valuation or external reporting (Hilton *et al*., 2008:147). Mowen *et al*. (2014:259) states that the ABC system is a two-stage process:

- Trace the costs to activities.
- Trace activity costs to cost objects.

The main assumption is that activities consume resources and cost objects consume activities (refer to Figure 2-3):



Source: (Modified) Mowen *et al.*, 2014:260.

Figure 2-3: Activity-Based Costing – Assigning overhead costs

Figure 2-3 exemplifies the two-stage ABC system whereby overhead costs are traced to activities and activities are traced to cost objects.

The "building" of an ABC system is divided into steps. Because the focus of ABC is on activities, the **first step** in designing an ABC system is to identify the activities related to the company's products. Activities can be identified in numerous ways including interviewing managers and

people in the functional work areas (Mowen *et al*., 2014:259-261; Hilton *et al*., 2008:147; Drury, 2008:229). The activities are captured in an activity dictionary that lists the activities performed by an organisation along with some critical activity attributes (Mowen *et al*., 2014:259-261; Hilton *et al*., 2008:147). Examples of activity attributes that can be used are (Mowen *et al*., 2014:261):

- Types of resources consumed.
- Amount (percentage) of time spent on an activity by workers.
- Cost objects that consume this activity output.
- Measure of the activity output (activity driver).
- Activity name.

As the activities are identified, it is classified as unit level, batch level, product level, customer level or facility level (Hilton *et al*., 2008:148).

The **second step** is to assign costs to activities. The resources that each activity consumes have to be identified; examples of resources are: labour, material, energy and capital. The costs of the resources are in the general ledger. The challenging part is to determine the portion of the resource consumed by the activity. To determine the quantity of the resources consumed by an activity, direct and driver tracing are required. Direct tracing is done when an activity consumes 100% of a resource. Alternatively an activity can consume a fraction of a resource, i.e. the resource is shared, in which case driver tracing is done. The drivers are then called resource drivers (Mowen *et al*., 2014:261-262; Drury, 2008:229).

The **third step** is to determine the cost driver rate for each activity. The costs from the second step are used to calculate the cost driver rate that is used to assign activity costs to goods and services. The rate should have a causal link to the cost. For example, the cost of running a truck will be determined by the number of hours that it is being used. Therefore an activity rate based on hours would be a logical choice (Hilton *et al*., 2008:148). The equation below illustrates the third step:

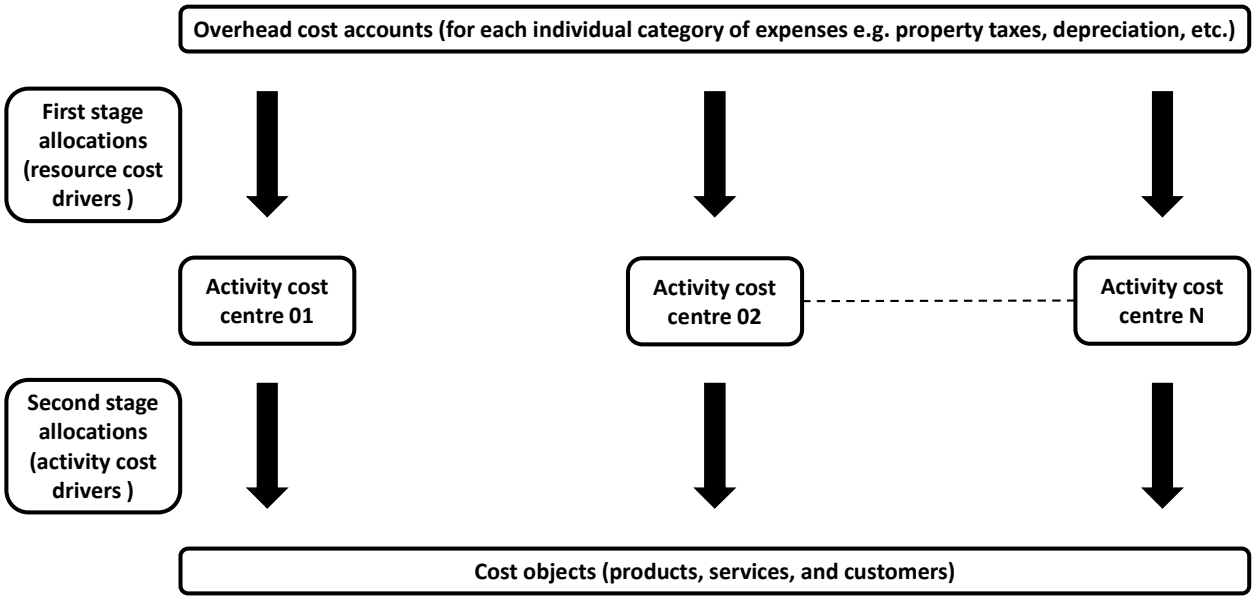
$$Cost\ driver\ rate = activity\ cost\ \div\ practical\ capacity\ of\ the\ activity$$

The **fourth step** is to assign activity costs to products (Hilton *et al*., 2008:148). The amount of each activity consumed by each product must be known (Mowen *et al*., 2014:265). The equation below illustrates the fourth step:

$$Product\ cost = Cost\ driver\ rate\ \times amount\ of\ the\ activity\ consumed$$

2.2.5 Activity cost pools

Drury (2008:223) uses the terms “activity cost pools” and “activity cost centres” interchangeably. An activity consists of an aggregation of many different tasks. An activity cost pool is a grouping of individual costs that are associated with a business activity (Accounting Tools, 2015; Houston Chronicle, 2015). The cost allocation process happens in two stages.



Source: Drury, 2008:224.

Figure 2-4: The two-stage overhead allocation process of an Activity-Based Costing system

Figure 2-4 exemplifies the two-stage overhead cost allocation process for an ABC system. The first stage is the allocation of overhead costs (resources) to activity cost pools by means of resource cost drivers. During the second stage the costs of activity cost pools are allocated to products or services (objects). A product or service is known as a cost object; therefore, activity cost pools are allocated to cost objects by means of activity cost drivers. An ABC system uses many activity cost drivers. The cost drivers are not necessarily volume-based. Examples of non-volume-based activity drivers are: the number of production runs for production scheduling and the number of purchase orders for the purchasing activity (Drury, 2008:223-224). Table 2-3 provides typical examples of activity cost pools (centres).

Table 2-3: Typical examples of activity cost pools and drivers

Activity Cost Pools	Activity Cost Drivers
Purchasing department	Number of purchase orders
Receiving department	Number of purchase orders
Materials handling	Number of materials requisitions
Setup	Number of machine setups required
Inspection	Number of inspections
Engineering department	Number of engineering change orders
Personnel processing	Number of employees hired or laid off
Supervisors	Number of direct labour hours

Source: CliffsNotes, 2014.

In the mining OPEX estimation process, the tendency is to roll up all the costs to an estimated annual cost. As a result certain functions are grouped together into “high level” activity cost pools. Often an activity cost pool can be subdivided into smaller “sub-pools”.

Table 2-4: Example of an activity cost pool in a mining project

Support Staff	} "High level" activity cost pool
Geology Department	} "Sub-pool" of "High Level" activity cost pool
Geology Manager	
Senior Geologist	
Geological Assistant	

Source: Own Research

For instance, referring to Table 2-4, Support Staff is a “high level” activity cost pool that consists of “sub-pools” such as the Geology Department which has numerous employees.

2.2.6 Time-Driven Activity-Based Costing

Maintaining the traditional ABC system can be costly, especially if the system uses many activity cost drivers (Hilton *et al.*, 2008:267). A “new” ABC was born: Time-Driven Activity-Based Costing (TDABC). TDABC addresses the limitations posed by ABC: it is simpler, less costly, faster to implement and allows activity cost driver rates to be based on the practical capacity of resources supplied (Srinivasan, 2008:22-23). In this revised approach of ABC, managers estimate the resource demands imposed by a transaction, product or customer. Traditional ABC first assigns the resource costs to activities and then to products or customers (Kaplan & Anderson, 2003:132). TDABC uses time as the cost driver to replace selected or all of the parts of an ABC system with

multiple activity cost drivers. The time to complete an activity is a sufficiently accurate measure to estimate the consumption of resources to produce a service or a product.

Given the fact that the conventional ABC system is costly, the question is: Is TDABC more cost effective? The answer is yes; because there is a single activity cost driver, namely time (Hilton *et al.*, 2008:267). TDABC requires two inputs: the cost per time unit of supplying resource capacity and the unit times of consumption of resource capacity by the product, service or customer (Hilton *et al.*, 2008:267; Srinivasan, 2008:24). TDABC enables managers to estimate the unit times for complex and specialised transactions (Kaplan & Anderson, 2003:132). The basic activity cost driver rate (cost per time unit of capacity) is calculated by applying the equation below (Hilton *et al.*, 2008:267; Srinivasan, 2008:25):

$$Cost\ per\ time\ unit\ of\ capacity = \frac{Total\ cost\ of\ supplying\ capacity\ to\ complete\ certain\ types\ of\ activities}{Total\ time\ (capacity)\ available\ to\ complete\ the\ activities}$$

Efficiency can be increased by reducing the time it takes to complete certain activities (without faltering on quality) (Hilton *et al.*, 2008:267). The decreased time will lead to cost savings as illustrated by the equation below:

$$Cost\ of\ completing\ activity = Cost\ per\ time\ unit\ of\ capacity\ \times Time\ taken\ to\ perform\ the\ activity$$

The time required to perform an activity can be obtained through direct observation or by interviews. It is not critical to be precise – rough estimates will suffice (Srinivasan, 2008:25).

2.2.6.1 The TDABC process

The TDABC process is twofold. Firstly the cost per time unit capacity has to be estimated and then the unit times of the activity has to be estimated.

Estimating the cost per time unit capacity: The main difference in estimating the cost per time unit capacity and traditional ABC is that the employees do not have to be surveyed to estimate

their time spend on an activity. Instead, the following steps are followed (Kaplan & Anderson, 2003:133):

- Estimate the resource practical capacity – The resource practical capacity is calculated as a percentage of the theoretical capacity. Kaplan and Anderson (2003:133) state that a rule of thumb assumption is to assume that the practical full capacity is 80% to 85% of the theoretical full capacity. For example, if an employee is available to work "x" hours per week, the practical full capacity is 0.80x to 0.85x. It would be reasonable to allow people a lower rate than equipment for breaks, arrivals, communication, etc. For the example 0.80x will be used as the practical full capacity.
- Extract the overhead cost from the company records that pertain to the example's employees. In this case set the overhead cost equal to "y".
- Now the cost per minute can be calculated:

$$Cost\ per\ minute = \frac{y}{(0.80)(x)(60)}$$

Estimating the unit times of activities: The time to carry out one unit of each kind of activity has to be determined. This can be done by (Kaplan & Anderson, 2003:133):

- Interviewing employees.
- Direct observation.
- In large companies it can be advantageous to conduct surveys. It must, however, be stressed that the actual time to carry out one unit of activity is required; not the percentage of time an employee spends on doing an activity.

For the example the unit times of activity will be set to "z" minutes. Hence, the cost of performing the activity will be:

$$Cost\ of\ performing\ the\ activity = (z)(cost\ per\ minute)$$

It is important to note that TDABC solves the challenge of surveyed employees responding as if their theoretical full capacity is fully utilised. As a result TDABC will have lower rates than the rates estimated through traditional ABC. The reason for this anomaly is because TDABC only

accounts for the portion of the practical capacity of the resources that were used for productive work. The total cost of overheads is not assigned to customers but rather a fraction of the total (Kaplan & Anderson, 2003:133; Srinivasan, 2008:26). In the above example the fraction of the overheads that will be billed to clients is 80% due to the practical full capacity of the employees being 80%.

TDABC enables managers to report costs on an ongoing basis in a way that will reveal both the costs of a business' activities as well as the time spent on the activities (Kaplan & Anderson, 2003:134; Srinivasan, 2008:27). TDABC also reveals the difference between the capacity supplied (quantity and cost) and the capacity used. Once identified it enables management to devise ways to reduce the unused capacity (Srinivasan, 2008:27). The TDABC model is easily updated because there are no interviews. To add activities, a manager simply has to estimate the unit time required for each activity. Also, the cost driver rates can easily be changed. Such a change will be required if, for example, the employees receive a salary raise or new equipment is introduced. A shift in efficiency is also easily captured – such a change will come as a result of continuous improvement efforts, re-engineering or the introduction of new technologies. The result will be that the same activity will be done in less time or with fewer resources; the TDABC analyst simply has to recalculate the unit time estimate (Kaplan & Anderson, 2003:134). The TDABC model can be updated in real time rather than on the calendar (once a quarter or annually) which provides a more accurate reflection of current conditions (Kaplan & Anderson, 2003:134; Srinivasan, 2008:27).

2.2.6.2 TDABC advantages

There are several benefits of TDABC, some of which are (Srinivasan, 2008:28-29):

- The equations used in the TDABC system are simple.
- The TDABC models are similar for companies in the same industry because the processes the companies follow are similar.
- The TDABC model reveals knowledge about efficiencies of business processes. Managers can be surprised at the cost of a special order, setting up a new client or a quality assurance check. Companies can enjoy immediate benefits from the TDABC model by focussing efforts on high cost and inefficient processes.
- The TDABC model can be used in a predictive manner. Costs can be predicted that can be used in discussions with clients.
- The TDABC model can be updated with ease.

2.3 Mining Resource Optimisation

2.3.1 Background

Great effort is put into deriving an estimated value of a mining project. This value is based on an assumed set (range) of conditions. Mining projects' complexity is such that the same project can have significantly varying values given the extent to which the project has been optimised. The assumptions that make up a "mid case" or "most likely case" typically are (Whittle *et al.*, 2007:1):

- Geology: tonnes, grades, variability and continuity.
- Geotechnical parameters: pit slopes or underground structures that can be supported, hydrology, civil works, berm construction, stockpile, waste and tailings competency.
- Mining cost, productivity and dilution; equipment productivity.
- Metallurgical cost, recovery and throughput.
- Market metal prices and, possibly, the demand for a certain product specification.

It is common that a single value is fed into the optimisation process for each of the above mentioned parameters. This is done in order to derive an accurate estimation of the project value as soon as possible. The reality is that there is very little information available for new projects because there is a lack of actual operating experience. The result is that many of the parameters could be in a fairly broad range and the values are likely to change as the project commences (Whittle *et al.*, 2007:2).

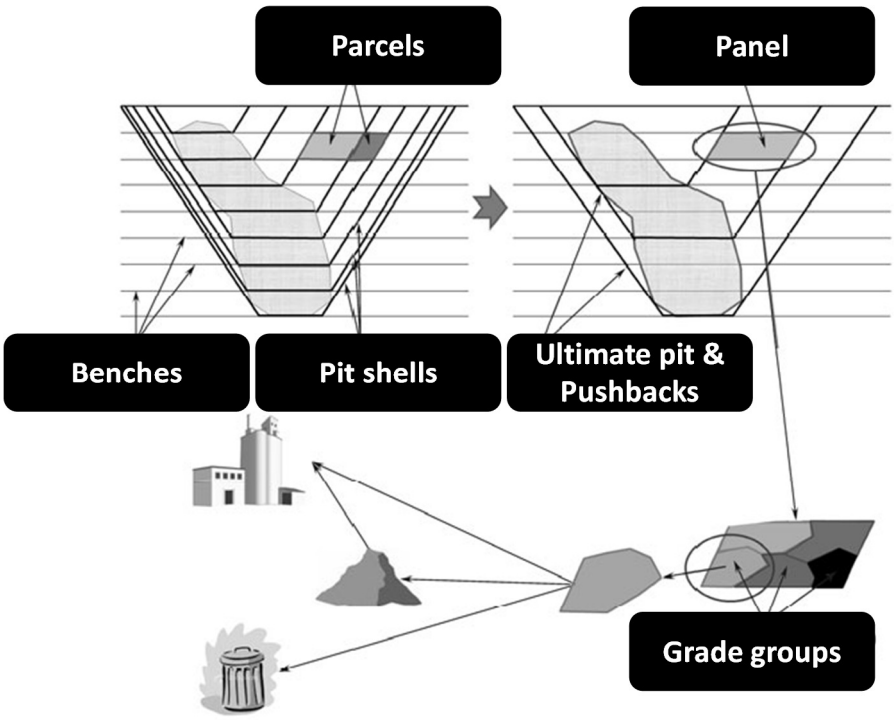
2.3.2 The strategic mine planning process

The mine design and production scheduling processes play crucial roles in the economic viability of a mine. In essence the mine design and production schedule provide a road map that should be followed from mine development to closure, i.e. what should be mined, where should it be sent and when this should be done (Dimitrakopoulos *et al.*, 2007:73; Elkington & Durham, 2011:177). Typically strategic mine planning is a sequential process of (Elkington & Durham, 2011:179):

- Generating a series of pit shells
- Selecting an ultimate pit
- Choosing intermediate pushbacks

Resource optimisation

- Selecting production capacities
- Production scheduling
- Cut-off and stockpile optimisation

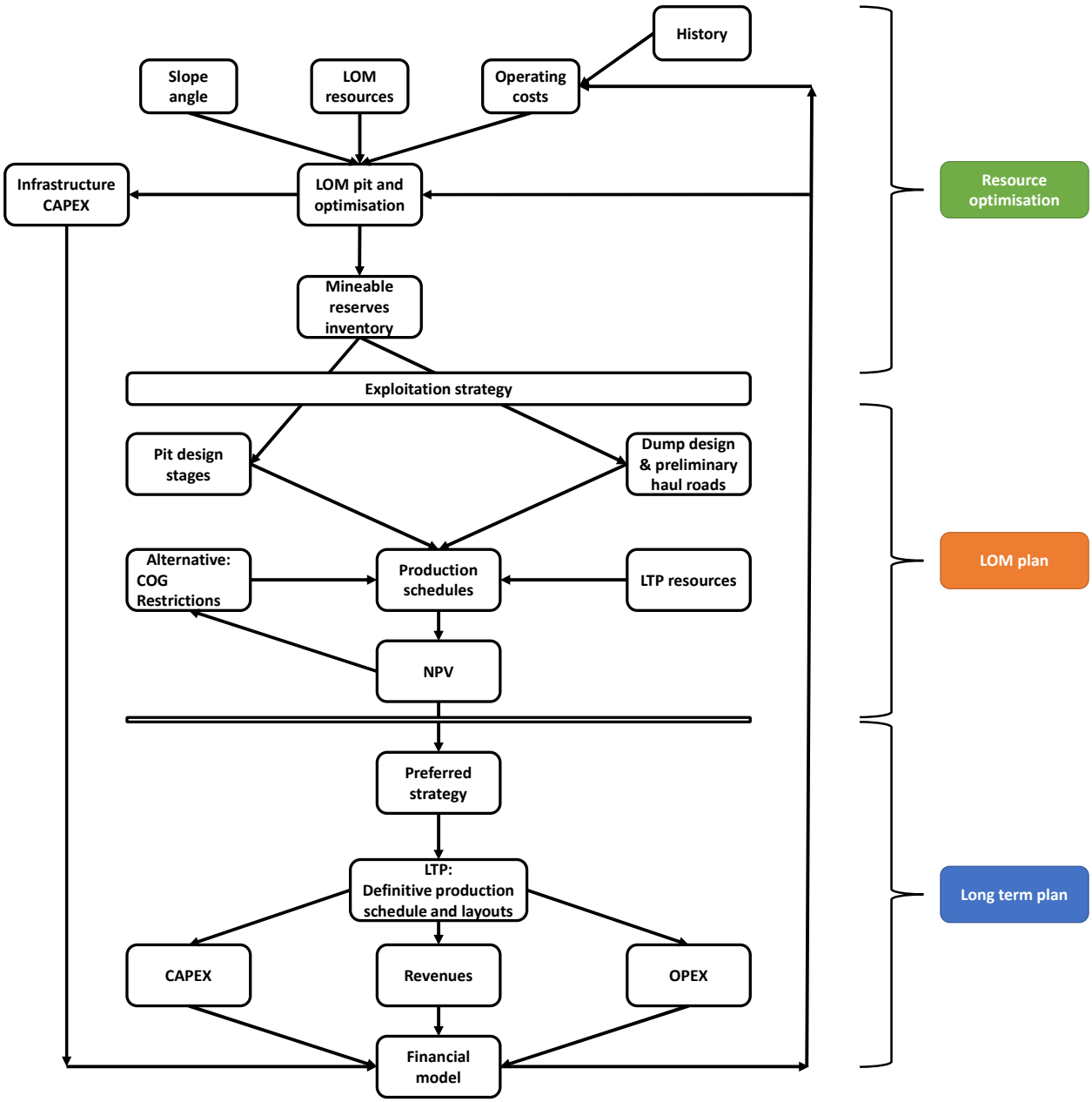


Source: Elkington & Durham, 2011:179.

Figure 2-5: The strategic mine plan

Figure 2-5 shows the series of nested pit shells that have been generated for the reserve. Also prevalent is the ultimate pit shell that has been chosen and the pushbacks within the ultimate pit.

Steffen (1997:51&52) illustrates the input, design processes and outputs of the mine planning process as depicted in Figure 2-6 (Steffen, 1997:52).



Source: (Modified) Steffen, 1997:52.

Figure 2-6: The mine planning process flow diagram

As illustrated in Figure 2-6 the mine planning process can be divided into three stages:

- Resource optimisation
- LOM planning
- Long term plan (LTP)

This study will focus on how the variable costs are fed into the resource optimisation process. The envisaged result will be different LOM pit boundaries each resulting in a unique NPV.

2.3.3 Resource optimisation

The prevailing resource optimisation method entails the application of the Lerchs-Grossman three-dimensional graph theory (LG) (Dimitrakopoulos *et al*., 2007:73). When the LG is applied it guarantees that, for a given input ore body model, geotechnical conditions and economic parameters, the value of the project will be maximised. The LG method of ore body optimisation can only take into account one ore body model and one set of economical and geotechnical parameters; uncertainty in the key input parameters leads to a sub-optimal NPV and deviations from the designed mine plan (Dimitrakopoulos *et al*., 2007:73; Whittle & Bozorgebrahimi, 2004:399). One of the main risks is the geological model; the geological model contains the volumes of the ore and waste that are present and the grades that are associated with the ore, for example the gold grade (Dimitrakopoulos *et al*., 2007:73). Dimitrakopoulos *et al*. (2007:73) presents an alternative to the, industry accepted, deterministic method of doing resource optimisation; a stochastic simulation that quantifies the grade uncertainty and the nested pit shells (developed with the LG algorithm). A risk assessment showed that the traditional mine plan development methodology has a 4% probability to attain its predicted NPV.

Traditional optimisation methods make an assumption of the commodity price; the mine plan is then based on this assumption and a given set of preferred economic criteria. Because the price is assumed, the mine plan will only be correct if the assumed price is correct; price estimations beyond 5 years are highly speculative. The planning process is continuous and is revised as the price changes – inevitably the mine designs will be inefficient because it is price sensitive. The reality is that every time the price changes, the economic footprint of the mine changes. Most mines do not produce volumes that will influence the commodity's price (supply and demand), therefore, the price should not be the only key parameter that is fed into the mine planning process (Steffen, 1997:47).

2.3.3.1 Defining the mining footprint

The aim of the optimisation process is to define the optimal footprint of the mine, given the prevailing economic parameters as well as physical parameters such as slope angles and constraints, like the lease area. In essence the aim of the optimisation process is to maximise the inventory that is deemed economical for exploitation. The LOM pit boundary delineates what is economic and uneconomic for exploitation; any ore beyond the boundary should not be recovered. The economic boundary for an open pit mine can be defined by (Steffen, 1997:49):

- The total ore reserve as represented in the geological block model.
- The marginal increment of mining costs that exceeds the expected income (this is where the limit of the open pit is reached).

- An underground operation becomes more profitable than an open pit.

The incremental cost is defined by the mining cost, therefore, when the incremental cost of mining the ore is too high, it is not included in the mining footprint (Steffen, 1997:49&51). Mining costs and revenue for each block in the block model vary randomly with time and location due to an increase in the variable cost as the ore / waste excavated deepens (in the case of a massive open pit) and / or the hauling distance (predominantly a factor in massive tabular ore bodies) to the tip / dump position and the commodity price vary (Frimpong & Achireko, 1997:45). It is common in industry to use NPV and IRR to determine whether a project is economically viable. However, these measurements (NPV and IRR) are not sensitive to the mining boundary. NPV and IRR are sensitive to, but not limited to, the (Steffen, 1997:49&51; Richmond, 2011:228):

- Mineral grades
- Mineral recovery
- Prevailing commodity price
- Production schedule / extraction sequence and timing
- Discount rate
- Operating cost
- Capital cost

The abovementioned “capital cost” forms part of the optimisation of the capacities and is of great importance because capacity has to be purchased either upfront or as part of the stay in business (SIB) capital and consequently has a great impact on the value of a project. A reduction in capacity does not always accompany recovery of the sunk cost due to excess capacity; worst case scenario will be that the cost is never recouped. The selected capacity does not only affect the capital expenditure but also the selected pit outlines, production schedule and cut-off grade (Elkington & Durham, 2011:178).

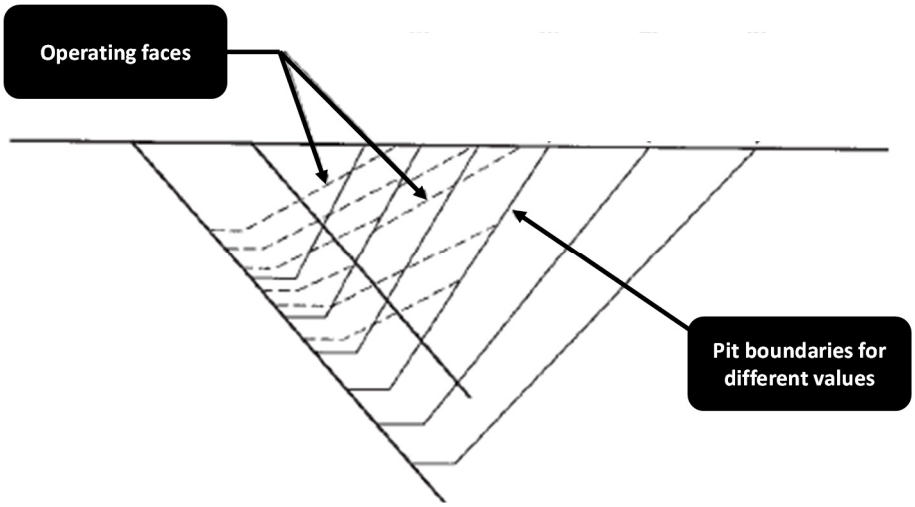
2.3.3.2 Nested pit shells

After the inventory and associated waste have been quantified, a long term mine plan has to be developed that must achieve the following objectives (Steffen, 1997:51):

- Maximise the value for the investors.
- Minimise the risk to investors.
- Maximise LOM.

Even though Steffen (1997:51) stated the above it has been proven in projects that maximising value and LOM can be contradicting. It is not a given that when the LOM is maximised the value will be at its peak; Figure 2-7 shows the pit boundaries for varying values (NPVs). From Figure

2-7 it can be seen that the mineable inventory decreases and increases as the value of the mine fluctuates. The mineable inventory is directly proportional to the LOM.



Source: Steffen, 1997:53.

Figure 2-7: Pit boundaries for varying NPVs

Whittle and Bozorgebrahimi (2004:399) refer to the different pit boundaries as “nested pit shells” or “hybrid pits” each of which has a varying degree of risk. These hybrid pits can be used to design the mine to an acceptable degree of risk. The advantage of using the hybrid pit methodology is that it allows the designer to manage the degree of risk and the value of the project. From experience the researcher has learned that the project charter will reflect the shareholder’s requirements. The requirements could, for example, state one of the following: maximise LOM at a zero NPV; maximise the NPV, etc. The mineable resource for each of the mentioned cases will be different. The main driver of the project charter is how the mine fits into the company’s business as a whole. It could be that the mine is supplying the company’s smelters in which case the project will not be profit driven but volume driven; i.e. maximise the LOM.

2.3.3.3 The production schedule

The production schedule is the sequence in which the mine is exploited (forms part of the mine plan). The mine footprint feeds into the production schedule, hence, the production schedule cannot be used as an input parameter during the optimisation phase (determining the optimum footprint). This ensures that when the inventory available for exploitation is determined, every block in the block model has an equal opportunity to contribute to the ultimate parameters – NPV and IRR (Steffen, 1997:49).

2.3.3.4 The optimisation process

Whittle *et al*. (2007:2) provides a detailed description of the typical process that is followed during the project optimisation phase. The aim of the project optimisation phase is to maximise the value of the project, given a set of input parameters / variables.

A geological model is created based on drilling that has been done. It is common practice to construct a block model in which each of the individual blocks is flagged, with the confidence level that the drilling in that area supports. There are three options to handle blocks with a low confidence interval:

- Move the blocks to the end of the production schedule.
- Leave the blocks in totality, i.e. reduce the resource volume.
- Discount the blocks.

From this point forward the geological model is considered as an accurate representation of the ore body and is effectively “locked”. Any changes to the geological model will result in significant re-work at later stages in the project.

Metallurgical recoveries are determined by test work. In many cases these recoveries are simply averaged out because of the uncertainty in the process of determining the recoveries; how representative the samples are of the ore body is as uncertain as the geological modelling process itself. The plant throughput is determined based on the engineering design. The planned ramp-up is determined and in certain cases the impact of a delayed ramp-up is investigated.

Usually the commodity price is varied as a worst, probable and best case. The commodity price applied can cause significant variance in the estimated value of a project. Depending on the project phase (scoping, pre-feasibility, or feasibility study) the level of the accuracy of engineering and mine design work will differ.

LG is applied with different revenue factors (for example 0.4 to 1.4) which provide a set of nested pit shells for a value based phasing strategy. After the nested shells have been generated the LOM production schedule is developed considering operational constraints such as (for a hard rock pits like gold or platinum, a commodity like coal could differ):

- The rate and location of mining.
- Cut-off grades between waste, stockpile and processing.
- The processing method a block will report to.
- Blend specifications.
- Production volume, mix and specifications.

If the optimisation process has been properly done, the result should be a production schedule that provides the maximum NPV that can be attained, given the assumptions / parameters mentioned earlier.

2.3.3.5 Characteristics of an optimised LOM plan

In order to maximise the NPV of a project, the optimiser (Whittle *et al*., 2007:2):

- Avoids “mining” anything where the cost outweighs the benefit.
- Brings larger positive cash flows forward in the production schedule.
- Delays negative cash flows.

An optimised LOM plan tends to have the following characteristics (Whittle *et al*., 2007:2):

- Initial waste stripping is postponed as far as possible and a “just in time” principle is followed with waste stripping. Enough waste is stripped so that the required amount of ore is fed to the plant. Whittle *et al*. (2007:2) refers to mining areas with the lowest stripping ratio first – the researcher, however, beliefs that a stripping ratio can be misleading. A vast number of variables determine the value of a block and it can happen that a block with a higher stripping ratio has a better value than a block with a lower stripping ratio, especially in massive tabular ore bodies such as coal.
- Initial higher head grades which will decline as the ore body is depleted until the cut-off grade is reached. As is the case with the stripping ratio the researcher is of the opinion that the higher head grades are not necessarily mined at the beginning of the production schedule and then gradually declines, because:
    - The ore body has a grade that varies unpredictably.
    - Of the vast number of variables that determine the value of a block.
- The resultant production schedule will either:
    - Decrease production rates if the system is input limited or
    - Increase mining and processing rates if the system is output limited

Common practice in the industry is to produce production schedules with smoothed mining and production rates, i.e. the volumes mined will be smoothed. This impacts negatively on the value of the project. It could be attributable to the human desire to keep the plant and equipment busy at all times or due to poor cost modelling that overstates the cost of labour and equipment on a short term basis. Possible solutions are (Whittle *et al*., 2007:2-3):

- Improved management.
- Sharing of assets.
- “Parking” assets, i.e. it could be more profitable to stop the plant or park haul trucks.

2.3.4 Prevailing cost application method

The prevailing process for open pit optimisation is to use computer software that applies the floating cone or LG algorithms together with the expected revenue and cost assigned to each block in the block model. The profit formula (Profit = Revenue - Cost) is applied to assign a value to each block in the block model. The software will then define the economic boundaries for the ore that is deemed economical for exploitation. Therefore, the ore inventory available for mining could have negative or positive values. Negative values could be included if the floating cone or LG algorithm has "probed" beyond the negative value and determined that there are positive values beyond the negative value that will have a greater positive effect on the NPV and IRR than the negative effect of the block with the negative value. The marginal / negative ore that is mined as part of the economic envelope can be treated in three manners (Steffen, 1997:49):

- Processed as ore.
- Stockpiled as a low grade ore.
- Discarded on the waste rock dumps.

Unit costs for each of the variables are fed into the mine planning process; Table 2-5 provides examples of typical unit costs.

Table 2-5: Typical unit costs and factors applied during mine planning

Variable	Unit
Ore price	$/t
Waste removal	$/t or $/m^3
Processing / Milling	$/t
Capital cost for processing capacity	$/t
Capital cost for mining capacity	$/t
Operating cost	$/t

Source: Richmond, 2011:231; Elkington & Durham, 2011:184; Dehghani & Ataee-pour, 2012:111

The budget of an organisation is determined by the estimated costs that it will incur, therefore, it is important to review and understand the way in which mining systems are costed. Incorrect costing could have a detrimental impact on the budget. Marginal projects could be wrongly implemented which will inevitably result in losses for the organisation (Lind, 2001:77). This notion gives rise to the question: What is the impact of the cost application method on the value of a mining project? Lind (2001:77) states that there is no single method of cost application that is the best; instead he proposes a hybrid of different methods.

Costs form part of the profit equation as expenditures (Lind, 2001:77):

$$Profit = Revenue - Expenditure$$

Cost (expenditure) is made up of two subsets: fixed costs and variable costs. Variable cost, essentially, equates to the Operating Expenditure (OPEX) of the mine (Lind, 2001:78):

$$Total\ cost = Total\ fixed\ cost + Total\ variable\ cost$$

Lind (2001:78) discusses two costing methods that he refers to as “traditional costing” and “alternative costing”. Traditional costing (process costing) defines the total cost as a unit cost. What this means is that both the variable and fixed costs are allocated to a product. In doing so it can happen that there will be cross-subsidisation of costs. This means that it will be impossible to determine the cost of a single function, such as loading, because a generalised cost will be obtained. Considering the above it is deduced that traditional costing systems utilise a single, volume based, cost driver. The challenge with this costing method is that it does not compliment a mine that produces two or more products; it is difficult to separate the mining activities for two products where blending is required. Blending is common practice in mines such as coal, iron ore and manganese where the quality of the product can be varied with blending and washing techniques. The traditional method results in the variable costs being absorbed by other costs, i.e. it is not possible to report the variable costs as a separate entity. Considering that the variable component of the costs is the manageable component of the total cost equation the problem with this costing technique is accentuated. The last shortfall of the traditional costing technique is that capital expenditure (CAPEX) is also defined as a unit cost, reiterating why costs are “blurred” by this technique and becomes unmanageable. No attempt is made to account the costs for individual units or specific groups of products. The shortfalls of the traditional costing method can be summarised as:

- Cross-subsidisation of costs.
- Capital costs are treated as period costs.
- The process, instead of specific groups of products, is costed.
- Almost impossible to account for multiple products.

2.3.5 Proposed cost application method

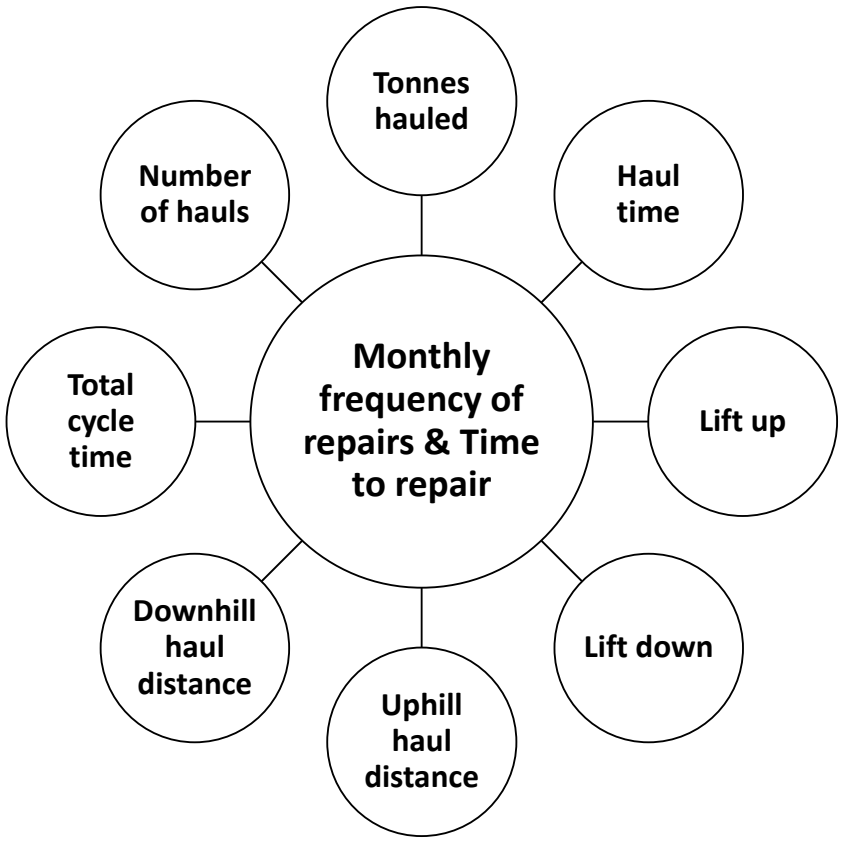
Lind (2001:79) proposes an alternative costing method to process costing (PC) – effectively a hybrid of different methods. Lind identified ABC as a more appropriate costing method for the

OPEX than process costing. Similarly Gunasekaran and Sarhadi (1998:231) note that experience has shown that the distortion in product costs can be reduced by applying ABC. The main difference is how ABC treats costs that are not related to a volume (indirect costs); with process costing the indirect costs are ignored. The indirect costs will no longer be absorbed by other cost pools, i.e. where these costs are significant, ABC will add value to the costing endeavour. Overhead costs are also treated differently. Overhead costs are grouped into a variety of activity-based cost centres that are linked to cost drivers. ABC assigns overhead costs to cost pools that represent the most significant activities in the mining process. Cost drivers are identified that "drive" each cost pool. Activity costs are assigned to cost objects that accurately measure the consumption of that activity. ABC aids a manager in his / her decision-making process in that it considers the direct and indirect activities and also tracks the costs i.e. ABC will allow for better decision making due to the way that it treats costs (Lind, 2001:79).

Lind (2001:82) compared ABC with PC when estimating the costs of a mining project – Lind used another study (conducted by Falconer in 1989) that was costed by the PC method as a baseline. Lind obtained a lower OPEX which significantly increased the value (NPV) of the system (project). The increased value is due to the relationship between profit and expenditure (profit = revenue - costs); when the expenditure is decreased the profit will increase. The reason for the lower OPEX is because ABC accounted for both direct and indirect costs and PC only used the major cost centres. An important factor that Lind mentions is that either one of the two systems does not estimate the cost correctly. In the case study that Lind did, where the ABC method provided a higher NPV, either ABC underestimated costs or PC overestimated costs. Lind argues that the way that ABC tracks the costs and that it is seen by many authors as a superior costing technique, PC overestimated the costs (in the case study Lind did). Lind recorded an NPV increase of 22% in the one system and 17% in the other when applying ABC as opposed to PC.

2.3.5.1 Example: Determining the full operating and maintenance costs for equipment

ABC will aid in determining the full operating and maintenance costs for each machine (Dessureault & Benito, 2012:73), however it is not limited to equipment.



Source: (Modified) Dessureault & Benito, 2012:75.

Figure 2-8: Machine usage parameters

Dessureault and Benito (2012:74) provide an example, exemplified in Figure 2-8, of the data required to predict the operational and maintenance cost for a haul truck. The data considered are:

- Operating cost: tonnes hauled, number of hauls, cycle time, haul time, lift up, lift down, uphill haul distance, downhill haul distance.
- Maintenance cost: monthly frequency of repairs, time to repair.

Although the data does not include the labour (operators) component and does not mention the diesel cost (R/l) and rate of consumption (l/h) it provides a good example of the type of data required for ABC.

How could the costs for a mining project be calculated? For example, the cost pool can be diesel. The driver will be the hours that a piece of equipment is operating at a pre-determined consumption rate (litres per hour). By calculating the product of the diesel cost, hours of operation, the litre per hour consumption rate and the number of equipment, the cost of the diesel cost pool can be calculated.

2.3.6 Summary

The purpose of this chapter was to provide a literature overview of the field of research. Section 2.2 – *Activity-Based Costing* discussed the background of ABC and why ABC is still a useful management tool for businesses today. Costs' behaviour was discussed so that costs can be classified as fixed or variable with respect to a measure of output or a driver. The cost hierarchy was discussed and a typical example of the ABC hierarchy as it would apply to a mining project was provided. A more in-depth look of ABC was taken and the steps necessary to design and ABC was discussed. Activity cost pools and the two-stage overhead allocation process of an ABC system were discussed. TDABC was introduced as an alternative to the traditional ABC system and some of the advantages of TDABC were supplied.

Section 2.3 – *Mining Resource Optimisation* focussed on mining resource optimisation that forms part of the strategic mine planning process. The prevailing resource optimisation process applies the LG algorithm to define the optimal mining footprint, given a set of economical and physical parameters. The cost application, during resource optimisation, is usually benchmarked unit costs. It was deduced that traditional costing systems utilise a single, volume based, cost driver. The shortfalls of the traditional costing systems are:

- Cross-subsidisation of costs.
- Capital costs are treated as period costs.
- The process instead of specific groups of products is costed.
- Almost impossible to account for multiple products.

The proposed, alternative, cost application method is ABC because of the way that ABC tracks costs. ABC is also seen, by many authors, as a superior costing technique.

The next chapter will focus on the optimisation of a hypothetical massive tabular coal deposit. The chapter will apply benchmarked unit costs as well as TDABC during the resource optimisation process. It is envisaged that multiple mining footprints will be generated, each with a unique NPV.

CHAPTER 3: RESOURCE OPTIMISATION CASE STUDY

3.1 Introduction

The previous chapter discussed the background of ABC and why ABC is still a useful management tool for businesses today. TDABC was introduced as an alternative to the traditional ABC system and some of the advantages of TDABC were supplied. The chapter also provides insight into mining resource optimisation that forms part of the strategic mine planning process. It is highlighted that the prevailing cost application, during resource optimisation, is usually benchmarked unit costs which has definite shortfalls. The proposed alternative cost application method is ABC because of the way that ABC tracks costs. ABC is also seen, by many authors, as a superior costing technique.

This chapter will focus on the optimisation of a hypothetical ore body using costing techniques such as TDABC as explained in Chapter 2. The ore body that will be used in the scenario is a massive tabular coal deposit. The economic footprint of the ore body will be optimised by applying six sets of variable costs. It is envisaged that six unique footprints will be obtained from each set of variable costs. A production schedule will be created for each of the footprints so that a free cash flow can be obtained for each. Two scenarios of free cash flows will be calculated for each of the production schedules / footprints: Scenario 01's free cash flows will use the variable costs that were applied to determine the footprints; Scenario 02's free cash flows will, exclusively, apply TDABC principles for the variable cost. The free cash flows will be used to calculate NPVs. The NPVs obtained will provide common ground upon which the footprints will be evaluated and recommendations will be made.

The following assumptions apply to the case study:

- The mining method is roll-over dozing strip mining – regardless of the thickness of the overburden.
- The operation is a contractor operation, therefore:
    - Working capital is zero.
    - Depreciation is zero.
- The overburden and coal does not require blasting, i.e. free-digging is possible by the loaders.

3.2 Geological resource

A hypothetical tabular coal deposit was developed for this study; the ore body was created in specialist mining software packages. The entire ore body was constructed in a block model.

3.2.1 Block model

A block model was created with a block size of 50 m x 50 m (refer to Figure 3-1). Each of the blocks were populated with the necessary data to derive a block model that contains the Run of Mine (ROM) tonnes that have been scheduled (production scheduling) to calculate the free cash flow.

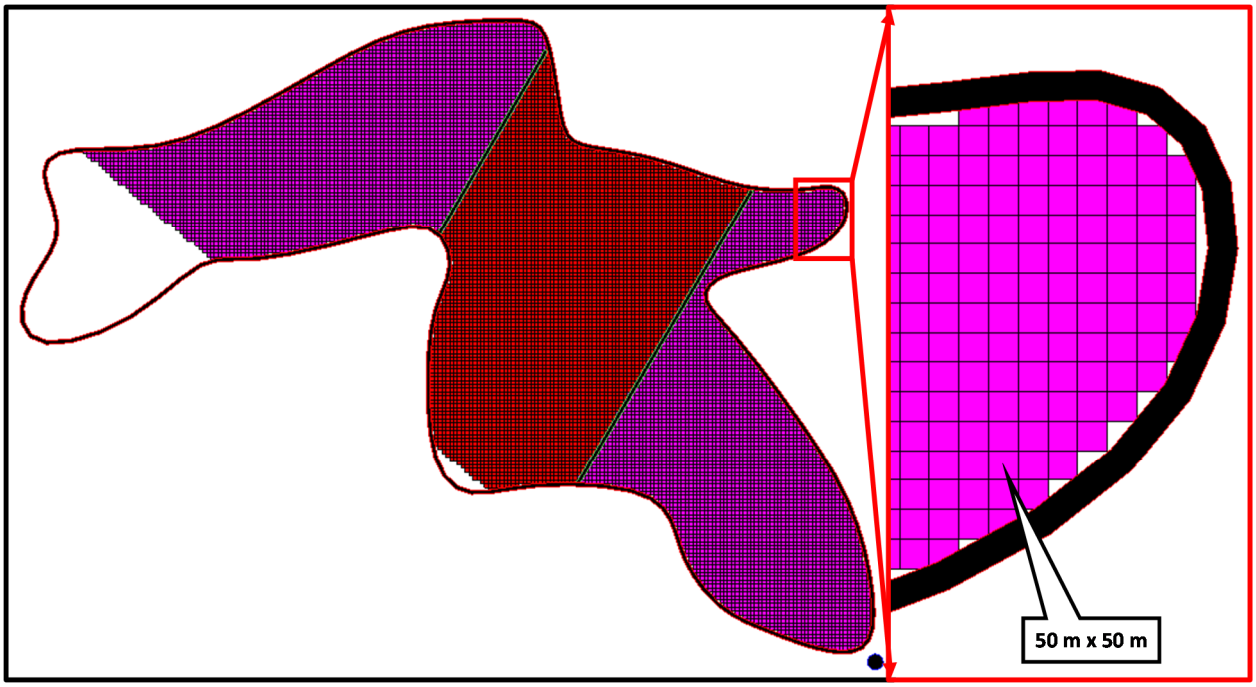


Figure 3-1: Block model

3.2.2 Resource characteristics

The hypothetical tabular coal deposit has unique characteristics; the key characteristics are discussed below.

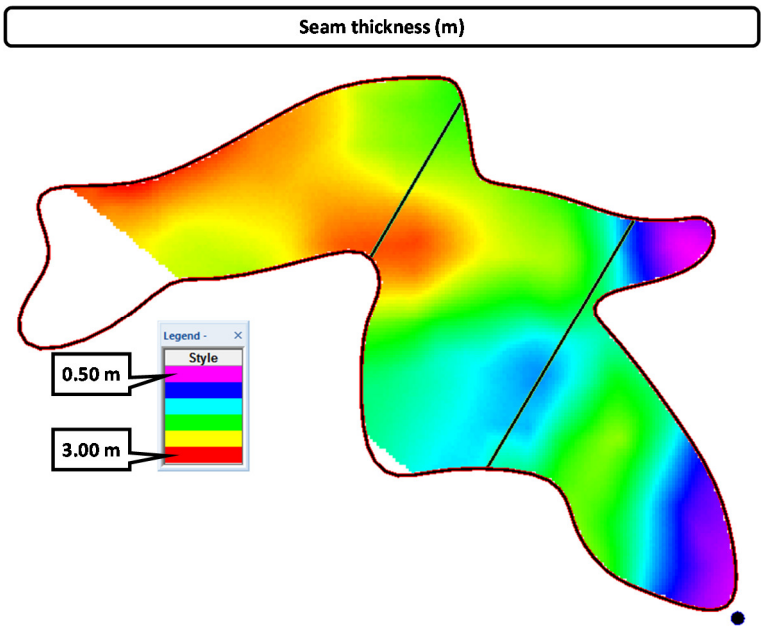


Figure 3-2: Coal seam thickness

The coal seam thickness varies between 0.50 m and 3.00 m (refer to Figure 3-2).

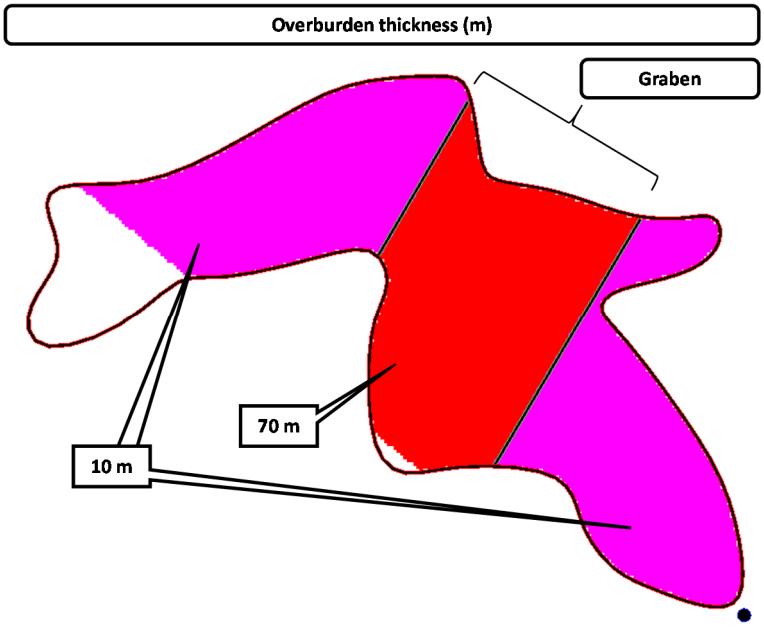


Figure 3-3: Overburden thickness

The seam is covered by a soft layer of overburden that allows for free-digging, i.e. no drilling and blasting are required. The overburden thickness varies between 10 m and 70 m (refer to Figure

3-3). The presence of the graben, depicted in Figure 3-3, is the cause for the variance in the overburden thickness.

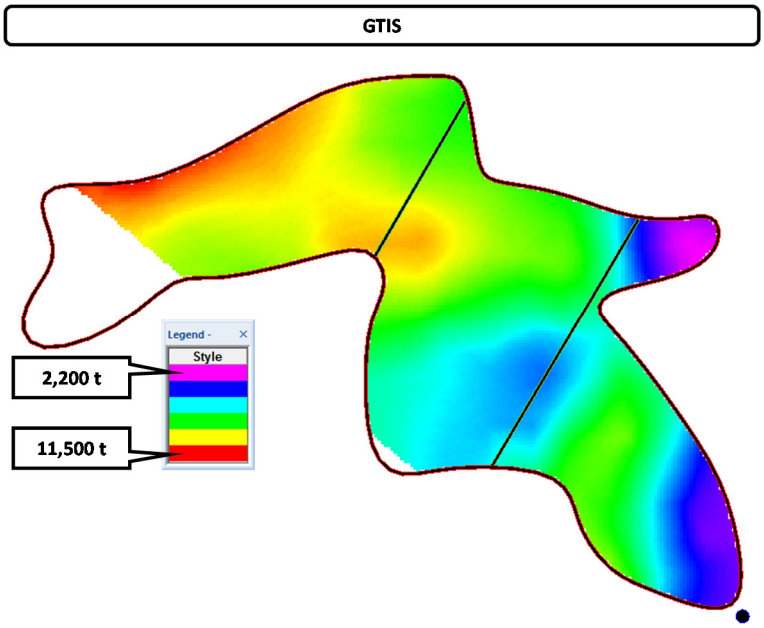


Figure 3-4: Gross Tonnes In Situ

Figure 3-4 shows the gross tonnes in situ (GTIS) of each 50 m x 50 m block – the total GTIS in the geological model is 101 Mt.

3.2.3 Geological to mining model conversion

The geological model contains the geologist's interpretation of the ore body. Due to inefficiencies and uncertainties (represented by the modifying factors) the entire ore body cannot be extracted. Firstly, the geological model is converted to a mining model. The mining model contains the volumes and tonnes of the ore body which the mining engineer deems practically extractible. To convert the geological model to a mining model the modifying factors, shown in Table 3-1, were applied. The resultant mining tonnes in situ (MTIS) are 91 Mt and the ROM tonnes are 90 Mt.

Table 3-1: Modifying factors

Modifying factor	Unit	Value
Geological loss	%	10
Contamination	%	5
Mining loss	%	5
Primary plant efficiency	%	90
Secondary plant efficiency	%	93

A geological loss of 10% has been applied together with contamination of 5% and a mining loss of 5% (refer to Table 3-1). The primary and secondary plant efficiency is 90% and 93% respectively. Table 3-2 shows a summary of the volumes present in the block model.

Table 3-2: Resource volumetrics

Variable	Unit	Value
GTIS	Mt	101
MTIS	Mt	91
ROMt	Mt	90
Export product	Mt	35
Domestic product	Mt	10
Discard	Mt	45

There are 101 Mt GTIS that reduces to 91 Mt and 90 Mt MTIS and ROMt, respectively, after the application of the modifying factors (refer to Table 3-1). The block model contains 35 Mt export product, 10 Mt domestic product and 45 Mt discard.

3.3 Economical footprint

To determine the economical footprint of a massive tabular ore body, a Value Distribution Model (VDM) is constructed. The VDM makes use of the profit formula as shown below:

$$Profit = revenue - cost$$

The input into this study's VDM is the mining and processing variable costs and the revenue. The term "value" is used because the value calculated for each block is not the profit, because only variable costs and no fixed costs are considered. The profit formula, for each individual block in the block model, is rewritten for the VDM as shown below:

$$Value\ (for\ each\ individual\ block\ in\ the\ block\ model) = revenue - variable\ mining\ and\ processing\ cost$$

For this study blocks with a value of zero and less have been excluded from the footprint, i.e. only blocks with a positive value is considered economic for exploitation. Six VDMs were constructed

to compare the difference in the NPV yielded by the different cost application methods. The costs applied to each VDM are:

- VDM 01: uses TDABC principles to calculate the variable costs.
- VDM 02: the total costs obtained from VDM 01 are recalculated to unit costs.
- VDM 03: the grand total cost obtained in VDM 01 is recalculated to a single unit cost.
- VDM 04: Wood MacKenzie data, based on export and domestic product tonnes, for a similar mine is used to calculate the variable costs.
- VDM 05: Wood MacKenzie data, based on total product tonnes, for a similar mine is used to calculate the variable costs.
- VDM 06: Benchmark data for a similar mine is used to calculate the variable costs.

3.3.1 VDM construction

The mine produces two products: export and domestic product. The selling price of the export product is set at R800 per tonne and the domestic product at R220 per tonne (refer to Table 3-3).

Table 3-3: Product selling prices

Selling prices		
Export product price	R/t	800.00
Domestic product price	R/t	220.00

The data, required for the costing calculations later on, which are acquired from the block model, are depicted in Table 3-4.

Table 3-4: Block model data

Data acquired from the block model		
ROM tonnes	t	Unique for each block in the block model
Haul distance	m	Unique for each block in the block model
Overburden volume	m^3	Unique for each block in the block model
Disturbed area	m^2	Unique for each block in the block model
Discard tonnes	t	Unique for each block in the block model
Export product tonnes	t	Unique for each block in the block model
Domestic product tonnes	t	Unique for each block in the block model

Each block in the block model has unique values for (refer to Table 3-4): ROM tonnes, the distance that the ROM tonnes are hauled from the pit to the tip / crusher, overburden volume, the area on surface that is disturbed to mining activities that has to be rehabilitated, discard tonnes in the plant, export product yield, domestic product yield.

3.3.1.1 Haul speed and dozer productivity calculations

The truck haul speed and dozer productivity have been calculated from the speed and productivity curves that are constructed by specialist software that simulates:

- Haul truck factors such as:
  - Road conditions
  - Distance hauled
  - Number of turns
  - Loading time
- Dozer factors such as:
  - Dozing distance
  - Overburden thickness
  - Strip width

The output of the specialist software simulation is data points for the hauling speed and dozer productivity. Linear interpolation, between adjacent points, is used to determine the haul speed and dozer productivity for an individual block in the block model.

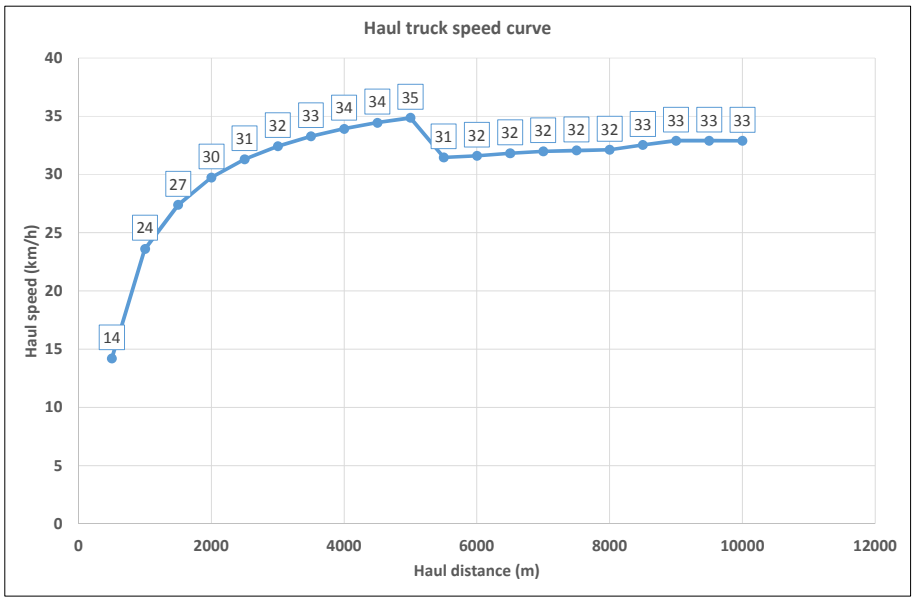


Figure 3-5: Haul truck speed curve

Figure 3-5 shows the haul truck speed curve that has been built into the VDM. The graph is “read” in conjunction with the haul distance to the tip / crusher to estimate the attained speed. For example: at a haul distance of 2,000 m the attained speed will be 30 km/h and at 4,000 m the attained speed will be 34 km/h.

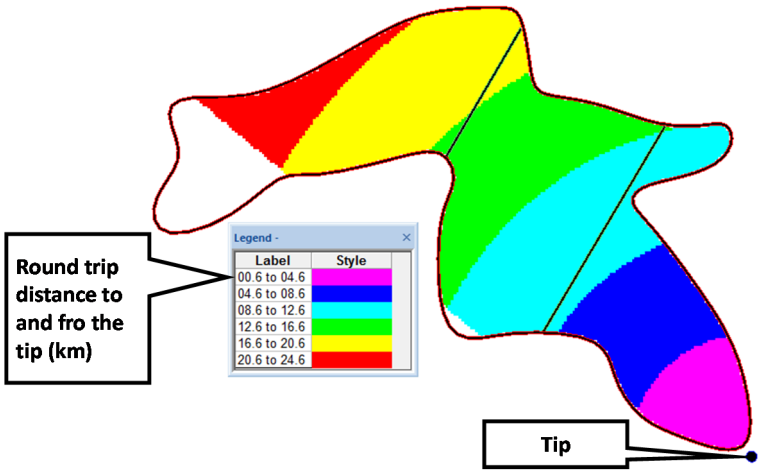


Figure 3-6: Round trip distance travelled by the haul truck

Figure 3-6 shows the haul distance that has been calculated as part of the VDM to estimate the speed that a haul truck will attain when hauling the ROM coal from the pit to the tip.

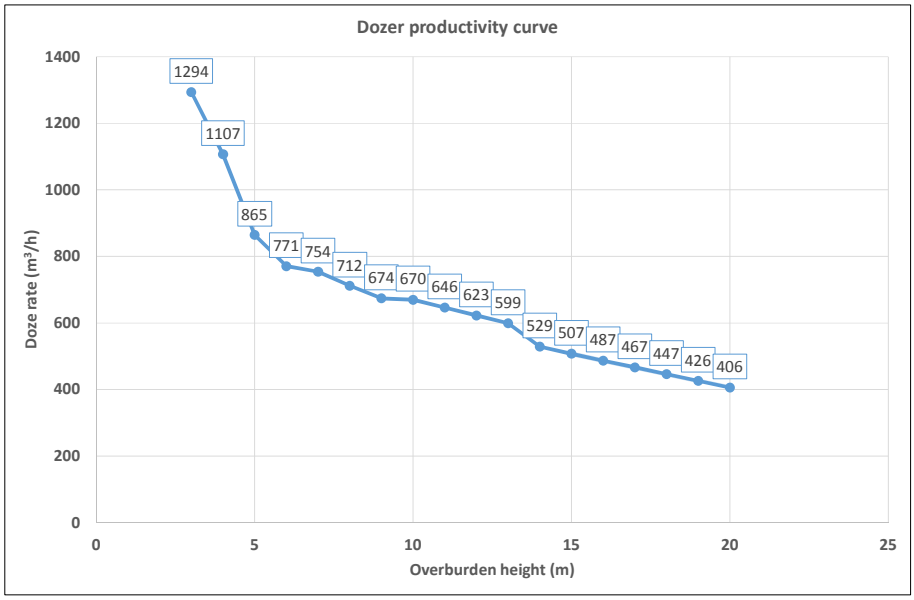


Figure 3-7: Dozer productivity curve

Figure 3-7 shows the dozer productivity curve that has been built into the VDM – the dozer rate is dependent on the overburden thickness of the specific block in the block model. For example: at an overburden thickness of 5 m, the dozer productivity will be 865 m^3/h and at an overburden thickness of 15 m, the dozer productivity will be 507 m^3/h.

3.3.1.2 VDM 01 Construction

VDM 01 uses TDABC principles to calculate the cost for each individual block in the block model. Table 3-5 shows the input data for VDM 01.

Table 3-5: VDM 01 Input data

VDM 01 Input data		
Labour	R/h	60.00
Diesel	R/l	10.00
Debushing	R/ha	20,000.00
Truck capacity	t/load	90.00
Truck burn rate	l/h	62.00
Truck OPEX	R/h	1,400.00
Shovel tempo	t/h	850.00
Shovel burn rate	l/h	210.00
Shovel OPEX	R/h	2,800.00
Dozer burn rate	l/h	230.00
Dozer OPEX	R/h	1,170.00
Processing rate	t/h	420.00
Processing OPEX	R/h	25,416.67
Processing discard handling	R/t	15.00

Because the mining method is roll-over dozing without blasting, the data depicted in Table 3-5 includes: debushing costs, labour costs, hauling costs, shovel costs, dozer costs and processing costs.

The following calculations have been performed to derive the value of each block in the block model:

Haul truck calculations – the haul truck calculations derive the total truck related costs based on TDABC principles.

$$Truck\ loads = ROM\ tonnes\ \div truck\ capacity$$

$$Load\ fixed\ time = 5\ \div 60$$

$$Speed\ attained = from\ \text{Figure 3-5}$$

$$Round\ trip\ distance = \ haul\ distance\ \times 2\ \div 1000$$

$$Round\ trip\ duration = round\ trip\ distance\ \div speed\ attained$$

$$Total\ cycle\ time = load\ fixed\ time + round\ trip\ duration$$

$$Truck\ total\ time = truck\ loads\ \times total\ cycle\ time$$

$$Truck\ diesel\ consumption = truck\ total\ time\ \times truck\ burn\ rate$$

$$Truck\ diesel\ cost = truck\ diesel\ consumption\ \times diesel\ cost$$

$$Truck\ OPEX\ cost = truck\ OPEX\ \times truck\ total\ time$$

$$Truck\ labour\ cost = labour\ cost\ \times truck\ total\ time$$

$$\boldsymbol{Truck\ total\ cost\ = truck\ diesel\ cost + truck\ OPEX\ cost + truck\ labour\ cost}$$

Shovel calculations – the shovel calculations derive the total shovel related costs based on TDABC principles.

$$Shovel\ load\ time = ROM\ tonnes\ \div shovel\ tempo$$

$$Shovel\ diesel = shovel\ load\ time\ \times shovel\ burnrate$$

$$Shovel\ diesel\ cost = shovel\ diesel\ \times diesel\ cost$$

$$Shovel\ labour\ cost = shovel\ load\ time\ \times labour\ cost$$

$$Shovel\ OPEX\ cost = shovel\ load\ time\ \times shovel\ OPEX$$

$$\boldsymbol{Shovel\ total\ cost = shovel\ diesel\ cost + shovel\ labour\ cost + shovel\ OPEX\ cost}$$

Dozer calculations – the dozer calculations derive the total dozer-related costs based on TDABC principles.

$$Dozer\ tempo = from$$ Figure 3-7

$$Dozer\ hours = overburden\ volume\ \div dozer\ tempo$$

$$Dozer\ diesel = dozer\ hours\ \times dozer\ burn\ rate$$

$$Dozer\ diesel\ cost = dozer\ diesel\ \times diesel\ cost$$

$$Dozer\ OPEX\ cost = dozer\ hours\ \times dozer\ OPEX$$

$$Dozer\ labour\ cost = dozer\ hours\ \times\ labour\ cost$$

$$\boldsymbol{Dozer\ total\ cost = dozer\ diesel\ cost + dozer\ OPEX\ cost + dozer\ labour\ cost}$$

Debushing calculations – the debushing calculations derive the total debushing cost based on ABC principles.

$$\boldsymbol{Debushing\ cost = debushing\ \times (area\ \div (100\ \times 100))}$$

Processing calculations – the processing calculations derive the total processing related costs based on TDABC principles.

$$Processing\ hours = ROM\ tonnes\ \div processing\ rate$$

$$Processing\ OPEX\ cost = processing\ hours\ \times processing\ OPEX$$

$$Processing\ discard\ cost = processing\ discard\ \times discard\ tonne$$

$$\boldsymbol{Processing\ total\ cost = processing\ OPEX\ cost + processing\ discard\ cost}$$

Total cost – the total cost calculation calculates the total variable cost for the haul truck, shovel, dozer, debushing and processing costs combined.

$$\boldsymbol{Total\ cost = truck\ total\ cost + shovel\ total\ cost + dozer\ total\ cost + debushing\ cost + processing\ total\ cost}$$

Revenue calculations – the total revenue calculation calculates the combined revenue of the sales of the export and domestic products.

$$Export\ product\ revenue = export\ product\ tonne \times export\ product\ price$$

$$Domestic\ product\ revenue = domestic\ product\ tonne \times domestic\ product\ price$$

$$\boldsymbol{Total\ revenue = export\ product\ revenue + domestic\ product\ revenue}$$

Value calculation – the value calculation calculates the value for each individual block in the block model when the total variable costs are subtracted from revenue.

$$\boldsymbol{Value = total\ revenue - total\ cost}$$

3.3.1.3 VDM 02 Construction

VDM 02 calculates unit costs (Rand per ROM tonne) from the total costs obtained from VDM 01 using the ROM tonnes encapsulated in the VDM 01 footprint. The unit costs are calculated by performing the following calculations:

$$VDM\ 02\ truck\ unit\ cost = truck\ total\ cost\ from\ VDM\ 01 \div total\ ROM\ tonnes\ from\ VDM\ 01\ footprint$$

$$VDM\ 02\ shovel\ unit\ cost = shovel\ total\ cost\ from\ VDM\ 01 \div total\ ROM\ tonnes\ from\ VDM\ 01\ footprint$$

$$VDM\ 02\ dozer\ unit\ cost$$
$$= dozer\ total\ cost\ from\ VDM\ 01$$
$$\div total\ Overburden\ volume\ from\ VDM\ 01\ footprint$$

$$VDM\ 02\ debush\ unit\ cost$$
$$= debushing\ cost\ from\ VDM\ 01$$
$$\div total\ disturbed\ area\ from\ VDM\ 01\ footprint$$

$$VDM\ 02\ processing\ unit\ cost$$
$$= \ processing\ total\ cost\ from\ VDM\ 01$$
$$\div total\ ROM\ tonnes\ from\ VDM\ 01\ footprint$$

The resultant unit costs are shown in Table 3-6.

Table 3-6: VDM 02 Input data

VDM 02 Input data		
Haul truck	R/ROMt	6.33
Shovel	R/ROMt	5.84
Dozer	R/m^3	7.97
Debushing	R/ha	20,000.00
Processing	R/ROMt	68.01

The value of each individual block in the block model is calculated by applying the following calculations:

Cost calculations – the cost calculations calculate the total cost for the combined truck costs, shovel costs, dozer costs, debushing costs and processing costs when the unit costs shown in Table 3-6 are applied.

$$VDM\ 02\ truck\ cost = \ VDM\ 02\ truck\ unit\ cost\ \times\ ROM\ tonnes$$

$$VDM\ 02\ shovel\ cost = VDM\ 02\ shovel\ unit\ cost\ \times\ ROM\ tonnes$$

$$VDM\ 02\ dozer\ cost = VDM\ 02\ dozer\ unit\ cost\ \times overburden\ volume$$

$$VDM\ 02\ debush\ cost = VDM\ 02\ debush\ unit\ cost\ \times disturbed\ area$$

$$VDM\ 02\ processing\ cost = VDM\ 02\ processing\ unit\ cost\ \times ROM\ tonnes$$

$$\boldsymbol{VDM\ 02\ total\ cost}$$
$$\boldsymbol{= VDM\ 02\ truck\ cost + VDM\ 02\ shovel\ cost + VDM\ 02\ dozer\ cost}$$
$$\boldsymbol{+ VDM\ 02\ debush\ cost + VDM\ 02\ processing\ cost}$$

Value calculation – the value calculation calculates the value of each individual block in the block model when the unit costs shown in Table 3-6 are applied and the revenue calculated in Section 3.3.1.2 – *VDM 01 Construction* is used.

$$\boldsymbol{VDM\ 02\ value = total\ revenue - VDM\ 02\ total\ cost}$$

3.3.1.4 VDM 03 Construction

VDM 03 calculates a single unit cost from the total cost obtained from VDM 01. The unit cost is calculated by performing the following calculation:

$$VDM\ 03\ unit\ cost = total\ cost\ from\ VDM\ 01\ \div\ total\ ROM\ tonnes\ from\ VDM\ 01\ footprint$$

The resultant unit cost is shown in Table 3-7.

Table 3-7: VDM 03 Input data

VDM 03 Input data		
VDM 03 unit cost	R/ROMt	169.63

The value of each individual block in the block model is calculated by applying the following calculations:

Cost calculation – the cost calculation calculates the total cost when the unit cost shown in Table 3-7 is applied.

$$\boldsymbol{VDM\ 03\ total\ cost = VDM\ 03\ unit\ cost\ \times ROM\ tonnes}$$

Value calculation – the value calculation calculates the value of each individual block in the block model when the unit costs shown in Table 3-7 are applied and the revenue calculated in Section 3.3.1.2 – *VDM 01 Construction* is used.

$$\boldsymbol{VDM\ 03\ value = total\ revenue - VDM\ 03\ total\ cost}$$

3.3.1.5 VDM 04 Construction

VDM 04 uses Wood MacKenzie data, based on export and domestic products, for a similar mine to calculate the costs. Table 3-8 shows the cost data that have been applied to derive a value for each block in the block model.

Table 3-8: VDM 04 Input data

VDM 04 Input data		
VDM 04 Mining domestic product	R/prodt	88.67
VDM 04 Preparation domestic product	R/prodt	22.77
VDM 04 Mining export product	R/prodt	138.73
VDM 04 Preparation export product	R/prodt	35.63

The value of each individual block in the block model is calculated by applying the following calculations:

Cost calculations – the cost calculations calculate the total cost when the Wood MacKenzie costs for mining and preparation are applied to the domestic and export products of each individual block in the block model.

$$VDM\ 04\ mining\ domestic\ product\ cost$$
$$= \text{VDM } 04\ mining\ domestic\ product\ \times domestic\ product\ tonnes$$

$$VDM\ 04\ preparation\ domestic\ product\ cost$$
$$= \text{VDM } 04\ preparation\ domestic\ product\ \times domestic\ product\ tonne$$

$$VDM\ 04\ mining\ export\ product\ cost = \text{VDM } 04\ mining\ export\ product\ \times export\ product\ tonne$$

$$VDM\ 04\ preparation\ export\ product\ cost$$
$$= \text{VDM } 04\ preparation\ export\ product\ \times export\ product\ tonne$$

$$\boldsymbol{VDM\ 04\ total\ cost}$$
$$= \boldsymbol{VDM\ 04\ mining\ domestic\ product\ cost}$$
$$+ \boldsymbol{VDM\ 04\ preparation\ domestic\ product\ cost}$$
$$+ \boldsymbol{VDM\ 04\ mining\ export\ product\ cost}$$
$$+ \boldsymbol{VDM\ 04\ preparation\ export\ product\ cost}$$

Value calculation – the value calculation calculates the value of each individual block in the block model when the unit costs shown in Table 3-8 are applied and the calculated revenue in Section 3.3.1.2 – *VDM 01 Construction* is used.

$$\boldsymbol{VDM\ 04\ value = total\ revenue - VDM\ 04\ total\ cost}$$

3.3.1.6 VDM 05 Construction

VDM 05 uses Wood MacKenzie data, based on total product tonnes, for a similar mine to calculate the costs. Table 3-9 shows the cost data that have been applied to derive a value for each block in the block model.

Table 3-9: VDM 05 Input data

VDM 05 Input data		
VDM 05 Mining cost	R/prodt	114.18
VDM 05 Preparation cost	R/prodt	29.32

The value of each individual block in the block model is calculated by applying the following calculations:

Cost calculations – the cost calculations calculate the total cost when the Wood MacKenzie costs for mining and preparation are applied to the domestic and export product of each individual block in the block model.

$$VDM\ 05\ mining\ cost = \text{VDM } 05\ mining\ cost \times (domestic\ product\ tonnes + export\ product\ tonnes)$$

$$VDM\ 05\ preparation\ cost = \text{VDM } 05\ preparation\ cost \times (domestic\ product\ tonnes + export\ product\ tonnes)$$

$$\boldsymbol{VDM\ 05\ total\ cost = VDM\ 05\ mining\ cost + VDM\ 05\ preparation\ cost}$$

Value calculation – the value calculation calculates the value of each individual block in the block model when the unit costs shown in Table 3-9 are applied and the calculated revenue in Section 3.3.1.2 – *VDM 01 Construction* is used.

$$\boldsymbol{VDM\ 05\ value = total\ revenue - VDM\ 05\ total\ cost}$$

3.3.1.7 VDM 06 Construction

VDM 06 applies benchmark data, for a similar mine, to calculate the variable costs. Table 3-10 shows the cost data that have been applied to derive a value for each block in the block model.

Table 3-10: VDM 06 Input data

VDM 06 Input data		
VDM 06 waste	R/m^3	22.07
VDM 06 mining	R/ROMt	7.52
VDM 06 processing	R/ROMt	18.08

The value of each individual block in the block model is calculated by applying the following calculations:

Cost calculations – the cost calculations calculate the total variable cost for each block in the block model.

$$VDM\ 06\ waste\ removal\ cost = VDM\ 06\ waste\ \times\ overburden\ volume$$

$$VDM\ 06\ mining\ cost = VDM\ 06\ mining\ \times ROM\ tonnes$$

$$VDM\ 06\ processing\ cost = VDM\ 06\ processing\ \times ROM\ tonnes$$

$$\boldsymbol{VDM\ 06\ total\ cost} = \boldsymbol{VDM\ 06\ waste\ removal\ cost} + \boldsymbol{VDM\ 06\ mining\ cost} + \boldsymbol{VDM\ 06\ processing\ cost}$$

Value calculation – the value calculation calculates the value of each individual block in the block model when the unit costs shown in Table 3-10 are applied and the calculated revenue in Section 3.3.1.2 – *VDM 01 Construction* is used.

$$\boldsymbol{VDM\ 06\ value = total\ revenue - VDM\ 06\ total\ cost}$$

3.3.2 Value Distribution Models' results

To determine the economic footprint of the resource, a Value Distribution Model (VDM) is constructed (refer to Section 3.3 – *Economical footprint*). For this study blocks with a value of zero and less have been excluded from the footprint, i.e. only blocks with a positive value is considered economic for exploitation. Figure 3-8 shows the legend that has been used for the VDM figures.

VDM legend

Label	Min	Max	Style
Less than zero	-100000000	0	
Zero to 0.7 mil	0	700000	
0.7 mil to 1.4 mil	700000	1400000	
1.4 mil to 2.1 mil	1400000	2100000	
2.1 mil to 2.8 mil	2100000	2800000	
2.8 mil to 3.5 mil	2800000	3500000	

Uneconomic

Economic

Figure 3-8: VDM legend

Figure 3-8 should be referenced when the VDM figures are viewed. Notice should be taken of blocks in the block model that have “uneconomic” values as these blocks have been excluded from the exploited footprint for the specified VDM scenario.

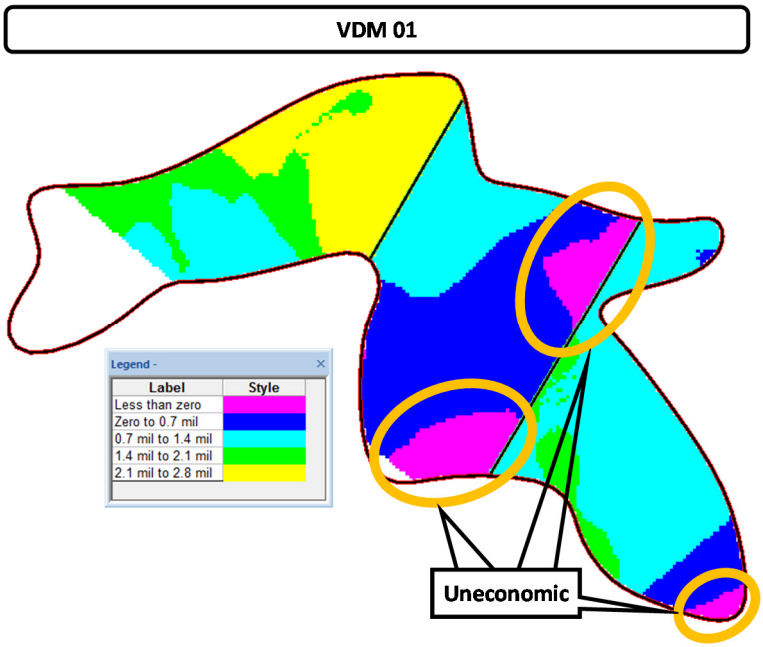


Figure 3-9: VDM 01

Figure 3-9 shows that VDM 01 has three areas that will be excluded from the exploited footprint considered for the scenario. Two of the uneconomic areas are situated in the graben and one is at the southernmost tip of the reserve.

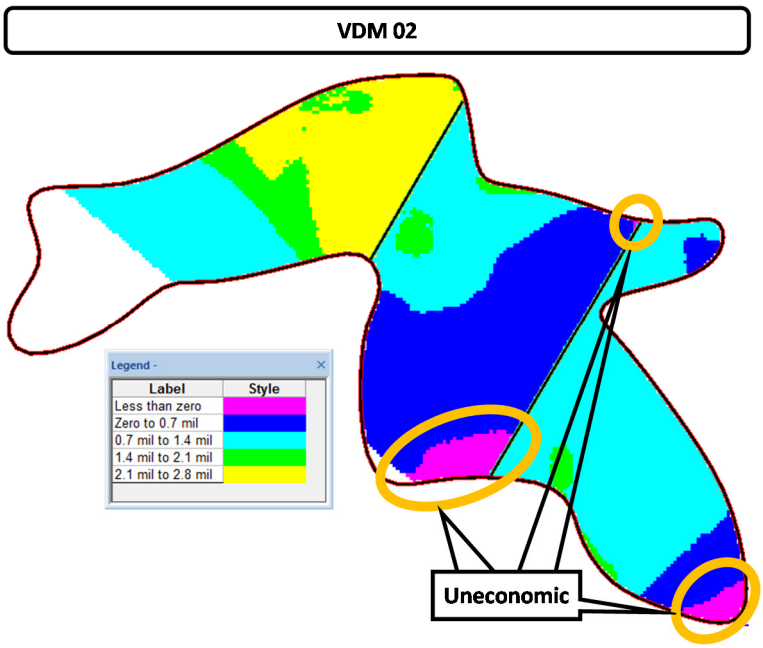


Figure 3-10: VDM 02

Figure 3-10 shows that VDM 02 has three areas that will be excluded from the exploited footprint considered for the scenario. Two of the uneconomic areas are situated in the graben and one is at the southernmost tip of the reserve.

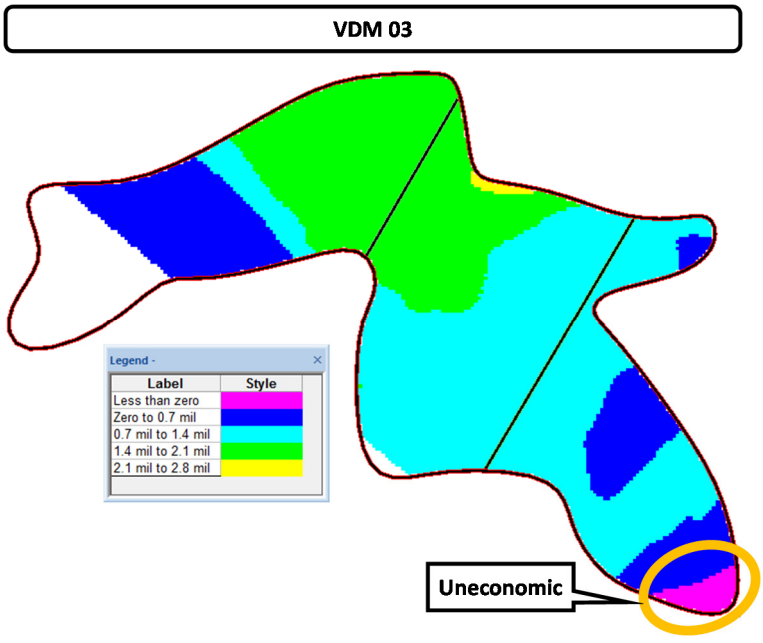


Figure 3-11: VDM 03

Figure 3-11 shows that VDM 03 has one area, at the southernmost tip of the reserve that will be excluded from the exploited footprint considered for the scenario.

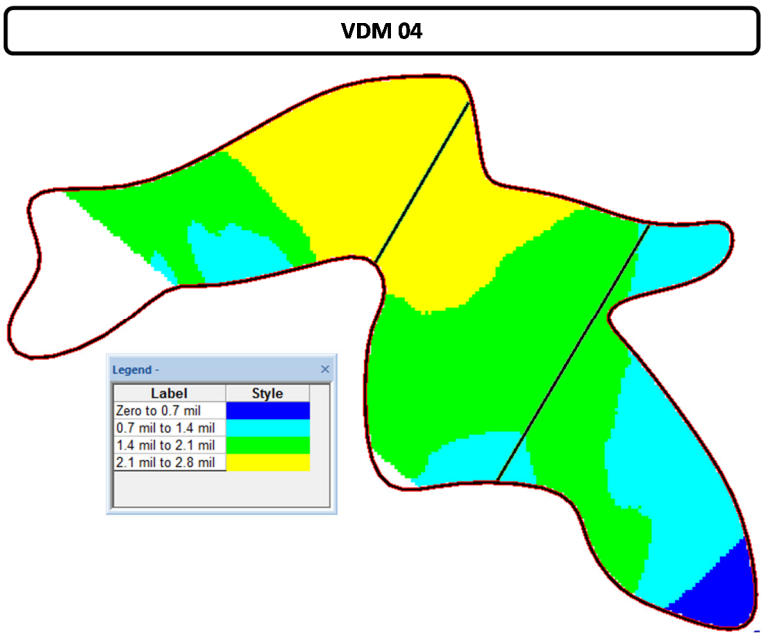


Figure 3-12: VDM 04

Figure 3-12 shows that VDM 04 will exploit the entire reserve.

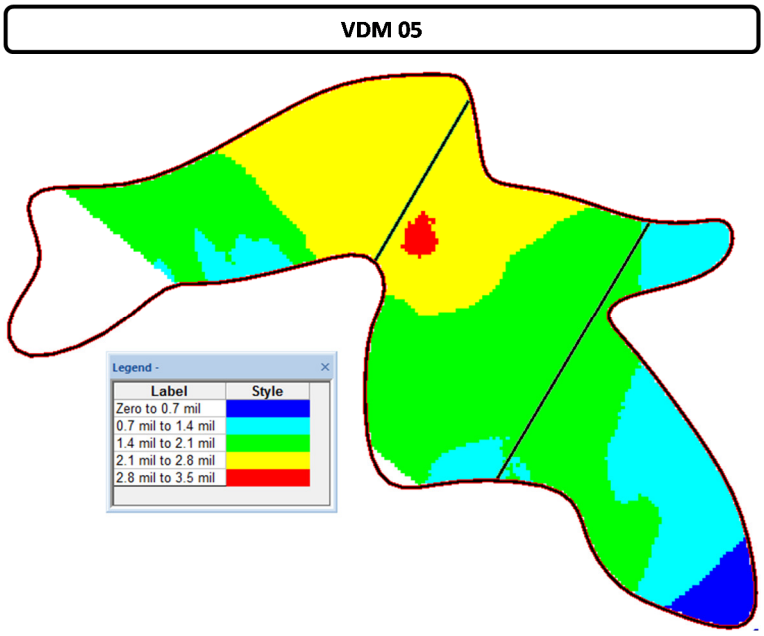


Figure 3-13: VDM 05

Figure 3-13 shows that VDM 05 will exploit the entire reserve.

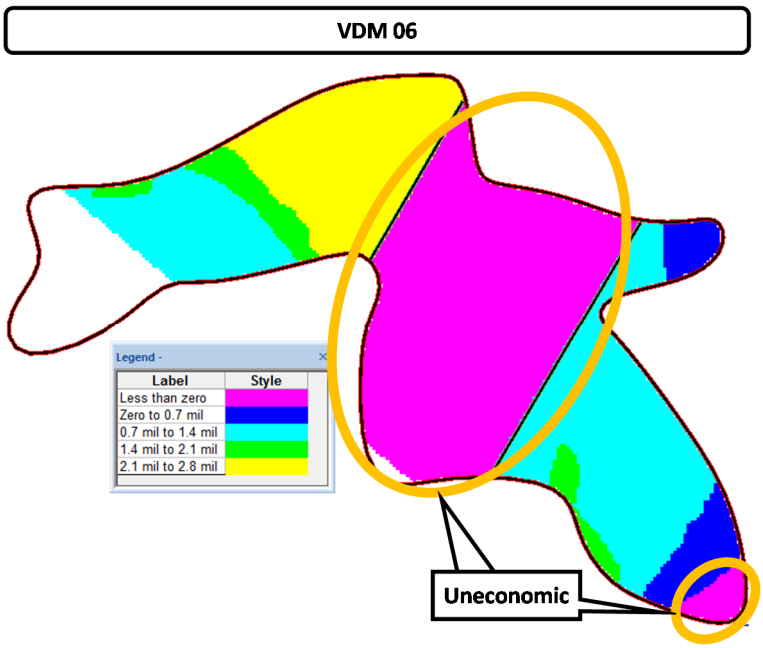


Figure 3-14: VDM 06

Figure 3-14 shows that VDM 06 will not exploit the southernmost tip of the ore body nor the entire graben area.

Because of the varying footprints of the VDMs the ROM tonnes of each footprint are unique; the ROM tonnes are as follows:

- VDM 01: 84.81 Mt
- VDM 02: 88.55 Mt
- VDM 03: 89.77 Mt
- VDM 04: 90.44 Mt
- VDM 05: 90.44 Mt
- VDM 06: 55.25 Mt

VDM 04 and VDM 05 have the same ROM tonnes, because neither exclude portions of the reserve (refer to Figure 3-12 and Figure 3-13).

3.4 Production scheduling

A production schedule is a simulation of the extraction sequence and date of extraction of the blocks in a block model. The production schedule provides a simulated flow of material extracted from the ore body in predefined time periods. For this study the production scheduling has been done in annual periods. The annual target is 2.5 Mt primary product. The annualised simulation provides an OPEX and revenue stream that can be incorporated in a financial model to calculate

the NPV of a production schedule. A period progress plot shows the sequence of extraction, in time, of the ore body that is simulated by the production schedule.

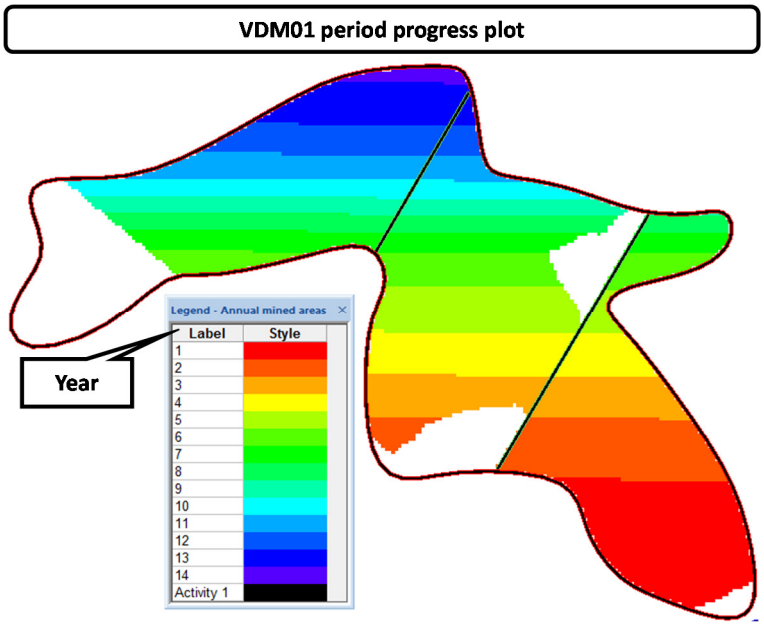


Figure 3-15: VDM 01 Period progress plot

Figure 3-15 shows the period progress plot of the production schedule that has been followed for VDM 01.

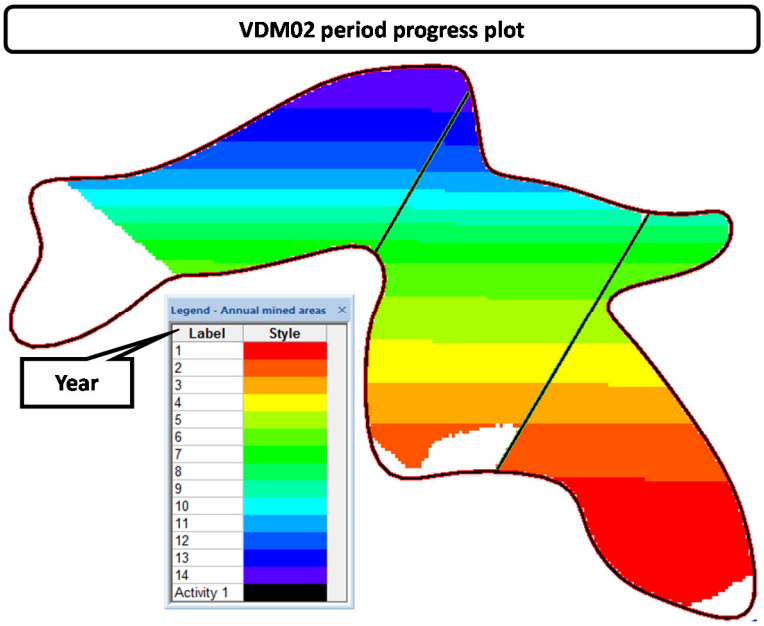


Figure 3-16: VDM 02 Period progress plot

Figure 3-16 shows the period progress plot of the production schedule that has been followed for VDM 02.

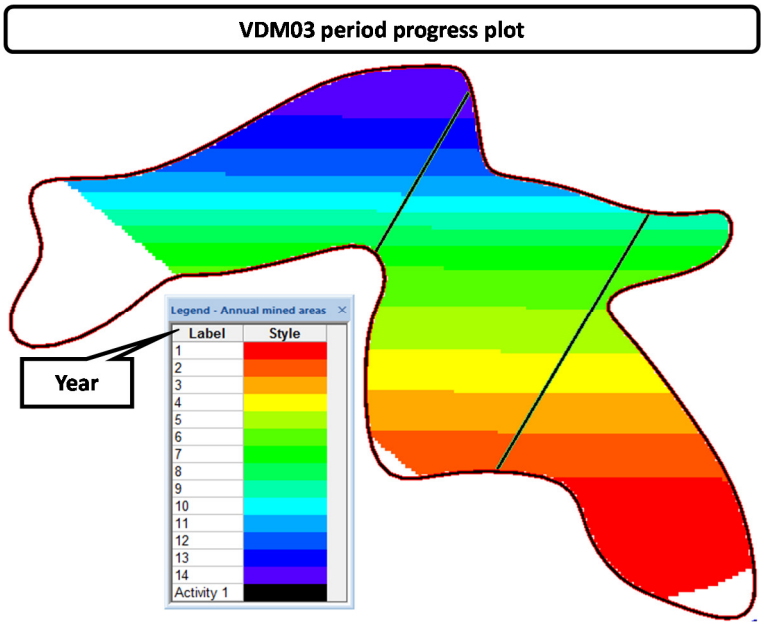


Figure 3-17: VDM 03 Period progress plot

Figure 3-17 shows the period progress plot of the production schedule that has been followed for VDM 03.

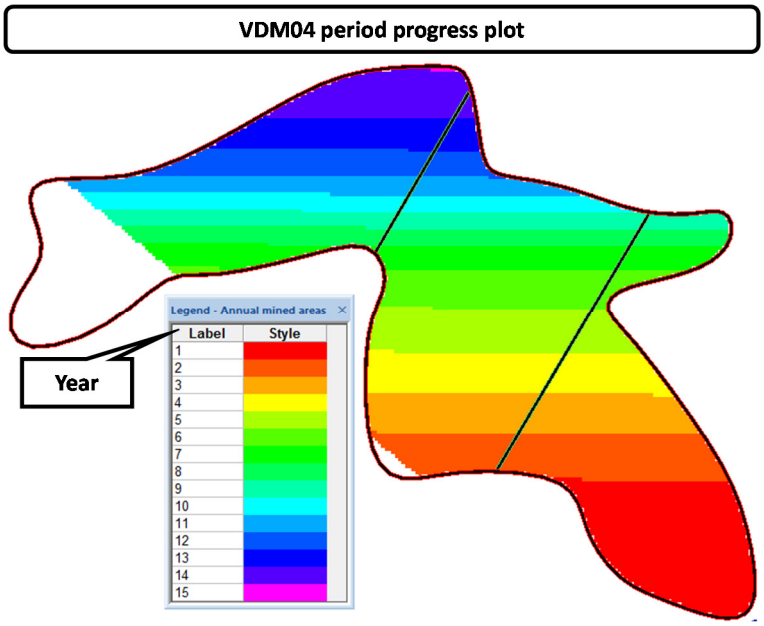


Figure 3-18: VDM 04 Period progress plot

Figure 3-18 shows the period progress plot of the production schedule that has been followed for VDM 04.

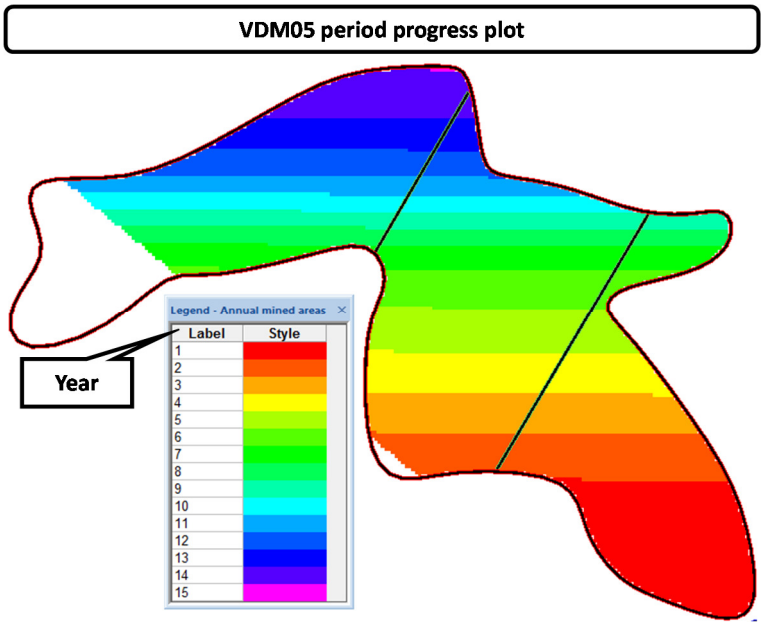


Figure 3-19: VDM 05 Period progress plot

Figure 3-19 shows the period progress plot of the production schedule that has been followed for VDM 05.

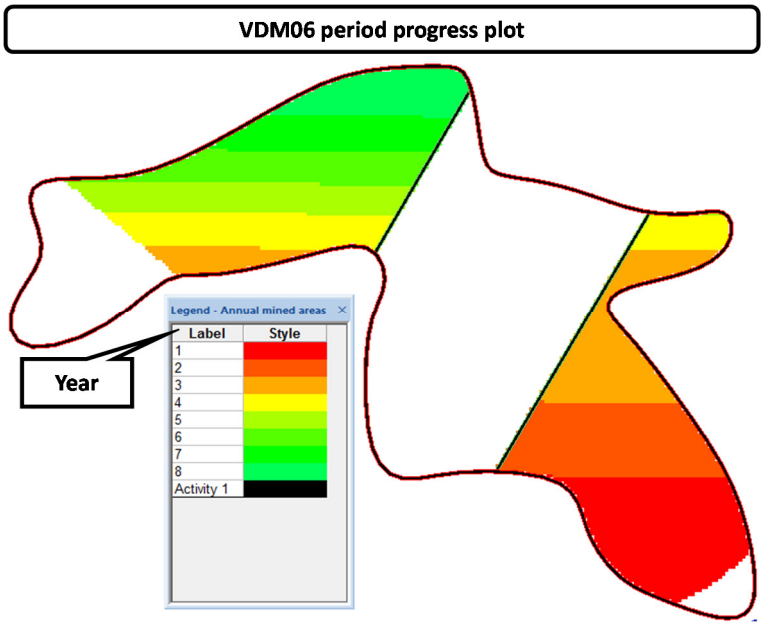


Figure 3-20: VDM 06 Period progress plot

Figure 3-20 shows the period progress plot of the production schedule that has been followed for VDM 06.

3.4.1 Production scheduling summary

Table 3-11 provides a summary of the production schedules for each of the six VDM footprints.

Table 3-11: Production scheduling summary

Production scheduling summary							
Variable	**Unit**	**VDM 01**	**VDM 02**	**VDM 03**	**VDM 04**	**VDM 05**	**VDM 06**
LOM	years	14.00	14.00	14.00	15.00	15.00	8.00
Total ROM	million t	84.81	88.55	89.77	90.44	90.44	55.25

VDM 01, VDM 02 and VDM 03 have a 14 year LOM; VDM 04 and VDM 05 have a 15 year LOM; and VDM 06 has the shortest LOM of 8 years (refer to Table 3-11). The ROM tonnes also show variance with the most significant variance being the 55.25 million ROM tonnes of VDM 06 as opposed to the other VDMs' ROM tonnes that vary between 84.81 and 90.44 million ROM tonnes (refer to Table 3-11).

3.5 Financial model

The following section develops the financial model; the purpose of the financial model is to convert the production schedules of each of the VDMs into a quantifiable figure that can be compared. Each of the VDMs has been analysed to determine its NPV. The focus of the analysis is on the variable cost and the discounted free cash flow (NPV) for each of the VDMs.

3.5.1 Financial model assumptions

The financial model requires assumed input variables that are used to derive the free cash flow of each of the VDMs – refer to Table 3-12 for the variable inputs.

Table 3-12: Financial model variable inputs

Variable	Unit	Value	Comment
Mining fixed cost	R/annum	100,000,000	
Processing fixed cost	R/annum	200,000,000	
Logistical cost	R/ROMt	10	
Royalties	%	3	
Depreciation	%	-	Zero because it is a contractor operation
CAPEX	R	50,000,000	Infrastructure at year zero: washing plant, crusher, offices etc.
Sustainable CAPEX	R	-	Zero because it is a contractor operation
Tax rate	%	35	
Discount factor	%	11	

Table 3-12 shows the variable inputs that have been incorporated in the financial model. The mining and processing fixed cost per annum amount to R100 million and R200 million respectively. A logistical cost of R10 per ROM tonne has been applied. Royalties and taxes are 3% and 35% respectively and the discount factor applied is 11%. The upfront CAPEX in the year before production starts, amounts to R50 million. It is assumed that it is a contractor operation, therefore, both depreciation and sustainable capital are zero.

3.5.2 Financial model construction

The financial model has been constructed to provide the NPV for each of the scenarios based on the calculations shown in Section 3.3.1 – *VDM construction*. To accentuate the different results (NPVs) obtained for the same ore body by means of different cost application methodologies, two NPV scenarios have been calculated:

- The first scenario's costs are based on the calculations shown in :
    - Section 3.3.1.2 – *VDM 01 Construction*
    - Section 3.3.1.3 – *VDM 02 Construction*
    - Section 3.3.1.4 – *VDM 03 Construction*
    - Section 3.3.1.5 – *VDM 04 Construction*
    - Section 3.3.1.6 – *VDM 05 Construction*
    - Section 3.3.1.7 – *VDM 06 Construction*
- The second scenario's costs are based on TDABC as shown in:
    - Section 3.3.1.2 – *VDM 01 Construction*

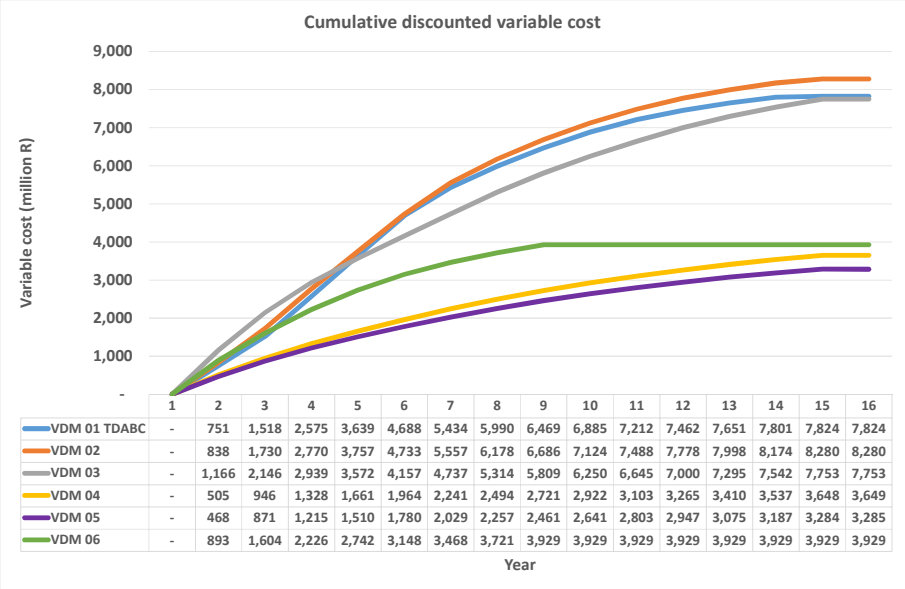
The reason for the two NPV scenarios is to show the NPV of each VDM's footprint when the costs used to delineate the footprint are used to determine the NPV vs applying TDABC for the NPV calculation of the different footprints.

3.5.3 Financial model results

To understand the behaviour of the variable costs and NPVs over time, cumulative graphs have been constructed for the discounted variable costs (DVCs) and discounted free cash flows (DFCFs). The cumulative discounted free cash flow provides the NPV of the production schedule in question at any given time.

3.5.3.1 Scenario 01

Figure 3-21 shows the cumulative DVC for Scenario 01. For example the cumulative DVC of VDM 01 is R2,575 million in year 4 and R7,212 million in year 11.

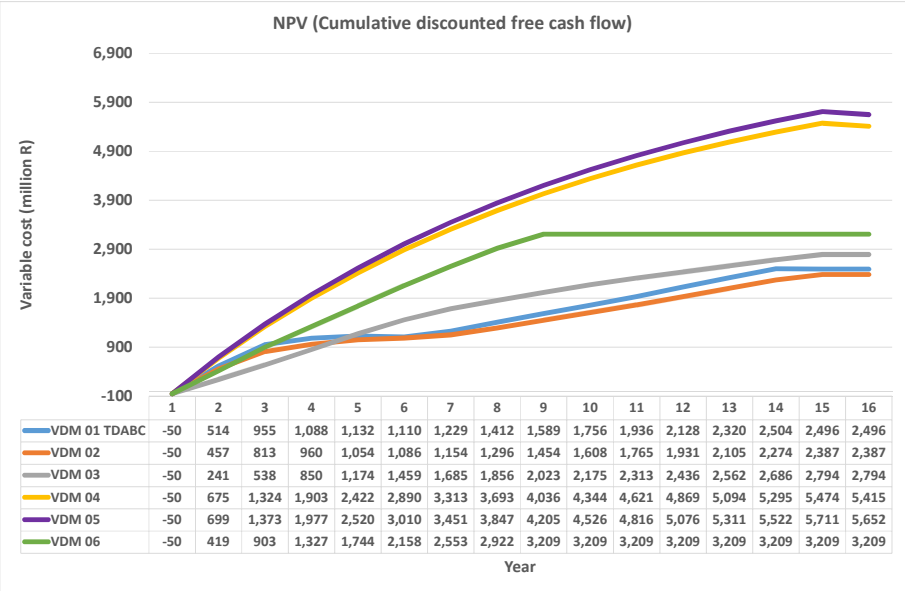


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
VDM 01 TDABC	-	751	1,518	2,575	3,639	4,688	5,434	5,990	6,469	6,885	7,212	7,462	7,651	7,801	7,824	7,824
VDM 02	-	838	1,730	2,770	3,757	4,733	5,557	6,178	6,686	7,124	7,488	7,778	7,998	8,174	8,280	8,280
VDM 03	-	1,166	2,146	2,939	3,572	4,157	4,737	5,314	5,809	6,250	6,645	7,000	7,295	7,542	7,753	7,753
VDM 04	-	505	946	1,328	1,661	1,964	2,241	2,494	2,721	2,922	3,103	3,265	3,410	3,537	3,648	3,649
VDM 05	-	468	871	1,215	1,510	1,780	2,029	2,257	2,461	2,641	2,803	2,947	3,075	3,187	3,284	3,285
VDM 06	-	893	1,604	2,226	2,742	3,148	3,468	3,721	3,929	3,929	3,929	3,929	3,929	3,929	3,929	3,929

Figure 3-21: Cumulative discounted variable cost

From Figure 3-21 it is concluded that the DVCs of each of the VDMs at year 16, in order of smallest to greatest, are: VDM 05 (R3,285 million); VDM 04 (R3,649 million); VDM 06 (R3,929 million); VDM 03 (R7,753 million); VDM 01 (R7,824 million); VDM 02 (R8,280 million).

When the variable costs, shown in Figure 3-21, are used as input to calculate the cumulative discounted free cash flow – which translates to the NPV – of each of the VDMs, the resultant graphic portrayed in Figure 3-22 is obtained. For example the NPV of VDM 04 is R1,324 million when the LOM is 3 years and R4,621 million when the LOM is 11 years.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
VDM 01 TDABC	-50	514	955	1,088	1,132	1,110	1,229	1,412	1,589	1,756	1,936	2,128	2,320	2,504	2,496	2,496
VDM 02	-50	457	813	960	1,054	1,086	1,154	1,296	1,454	1,608	1,765	1,931	2,105	2,274	2,387	2,387
VDM 03	-50	241	538	850	1,174	1,459	1,685	1,856	2,023	2,175	2,313	2,436	2,562	2,686	2,794	2,794
VDM 04	-50	675	1,324	1,903	2,422	2,890	3,313	3,693	4,036	4,344	4,621	4,869	5,094	5,295	5,474	5,415
VDM 05	-50	699	1,373	1,977	2,520	3,010	3,451	3,847	4,205	4,526	4,816	5,076	5,311	5,522	5,711	5,652
VDM 06	-50	419	903	1,327	1,744	2,158	2,553	2,922	3,209	3,209	3,209	3,209	3,209	3,209	3,209	3,209

Figure 3-22: Cumulative discounted free cash flow

The NPVs for a 16 year LOM of Scenario 01, in order of smallest to largest, are (refer to Figure 3-22): VDM 02 (R2,387 million); VDM 01 (R2,496 million); VDM 03 (R2,794 million); VDM 06 (R3,209 million); VDM 04 (R5,415 million); VDM 05 (R5,652 million). The order of the NPVs is the reverse of the order of the DVCs shown in Figure 3-21. Table 3-13 provides a summary of the Scenario 01 results.

Table 3-13: Scenario 01 – results summary

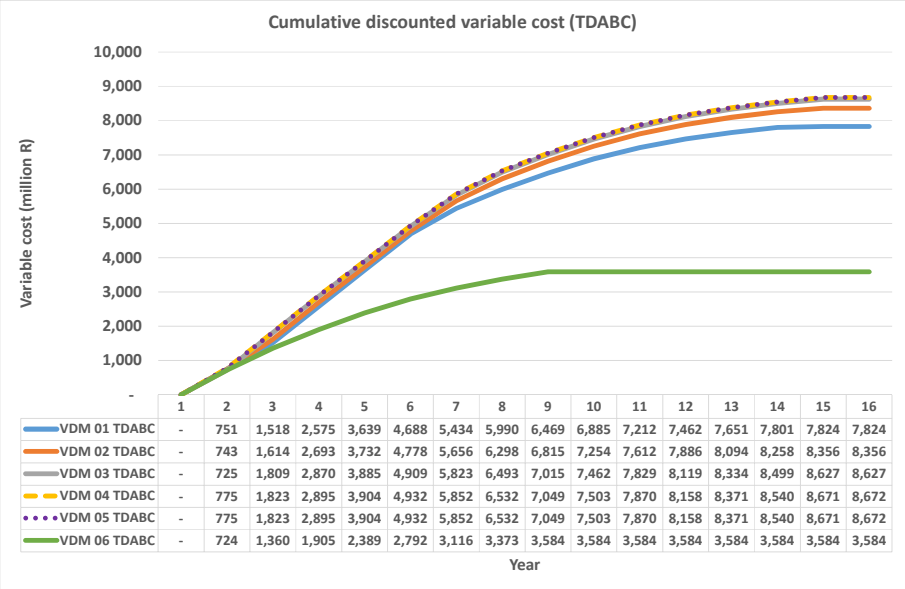
Scenario 01 (LOM = 16 years)							
Variable	**Unit**	**VDM 01**	**VDM 02**	**VDM 03**	**VDM 04**	**VDM 05**	**VDM 06**
DVC	million R	7,824.34	8,279.61	7,753.21	3,649.49	3,284.75	3,928.77
NPV	million R	2,495.62	2,386.61	2,793.87	5,414.85	5,651.99	3,209.36

From Table 3-13 it can be seen that the NPVs are the inverse of the DVCs. VDM 02 had the highest DVC (R8,279 million) and the lowest NPV (R2,386 million) and VDM 05 the lowest DVC (R3,284 million) and the highest NPV (R5,651 million).

3.5.3.2 Scenario 02

Figure 3-23 shows the cumulative DVC for Scenario 02; the costs are calculated according to the TDABC principles shown in Section 3.3.1.2 – *VDM 01 Construction*. For example VDM 02 has a cumulative DVC of R1,614 million at year 3 and R6,815 million at year 9. Because the variable

costs are calculated according to TDABC principles, it is foreseen that VDMs with the same footprint will result in the same DVC at any given time.

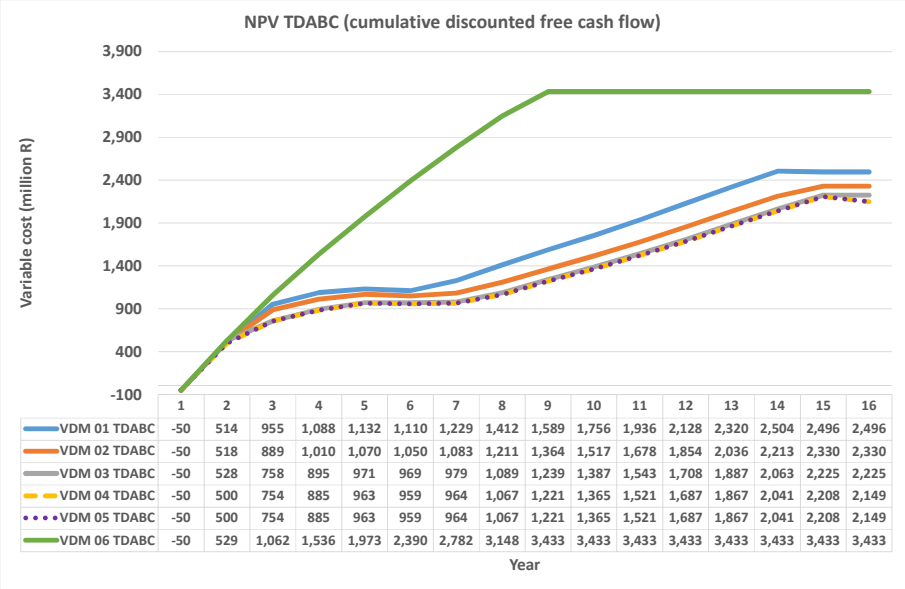


	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
VDM 01 TDABC	-	751	1,518	2,575	3,639	4,688	5,434	5,990	6,469	6,885	7,212	7,462	7,651	7,801	7,824	7,824
VDM 02 TDABC	-	743	1,614	2,693	3,732	4,778	5,656	6,298	6,815	7,254	7,612	7,886	8,094	8,258	8,356	8,356
VDM 03 TDABC	-	725	1,809	2,870	3,885	4,909	5,823	6,493	7,015	7,462	7,829	8,119	8,334	8,499	8,627	8,627
VDM 04 TDABC	-	775	1,823	2,895	3,904	4,932	5,852	6,532	7,049	7,503	7,870	8,158	8,371	8,540	8,671	8,672
VDM 05 TDABC	-	775	1,823	2,895	3,904	4,932	5,852	6,532	7,049	7,503	7,870	8,158	8,371	8,540	8,671	8,672
VDM 06 TDABC	-	724	1,360	1,905	2,389	2,792	3,116	3,373	3,584	3,584	3,584	3,584	3,584	3,584	3,584	3,584

Figure 3-23: Cumulative discounted variable cost – TDABC

From Figure 3-23 it is concluded that the DVCs at year 16, in order of smallest to largest, are: VDM 06 (R3,584 million); VDM 01 (R7,824 million); VDM 02 (R8,356 million); VDM 03 (R8,627 million); VDM 04 (R8,672 million) and VDM 05 (R8,672 million). As expected VDM 04 and VDM 05 have the same DVCs because their footprints are exactly the same.

When the variable costs, shown in Figure 3-23, are used as input to calculate the NPVs for Scenario 02 the resultant graphic is Figure 3-24. For example, the NPV of VDM 06 is R2,390 million for a LOM of 6 years and R3,433 million for a LOM of 9 years.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
VDM 01 TDABC	-50	514	955	1,088	1,132	1,110	1,229	1,412	1,589	1,756	1,936	2,128	2,320	2,504	2,496	2,496
VDM 02 TDABC	-50	518	889	1,010	1,070	1,050	1,083	1,211	1,364	1,517	1,678	1,854	2,036	2,213	2,330	2,330
VDM 03 TDABC	-50	528	758	895	971	969	979	1,089	1,239	1,387	1,543	1,708	1,887	2,063	2,225	2,225
VDM 04 TDABC	-50	500	754	885	963	959	964	1,067	1,221	1,365	1,521	1,687	1,867	2,041	2,208	2,149
VDM 05 TDABC	-50	500	754	885	963	959	964	1,067	1,221	1,365	1,521	1,687	1,867	2,041	2,208	2,149
VDM 06 TDABC	-50	529	1,062	1,536	1,973	2,390	2,782	3,148	3,433	3,433	3,433	3,433	3,433	3,433	3,433	3,433

Figure 3-24: Cumulative discounted free cash flow – TDABC

The NPVs for a 16 year LOM for Scenario 02, in order of smallest to largest NPV (refer to Figure 3-24), is: VDM 04 (R2,149 million) and VDM 05 (R2,149 million); VDM 03 (R2,225 million); VDM 02 (R2,330 million); VDM 01 (R2,496 million); VDM 06 (R3,433 million). The order of the NPVs is the reverse of the order of the DVCs shown in Figure 3-23. Table 3-14 provides a summary of the Scenario 02 results.

Table 3-14: Scenario 02 – results summary

Scenario 02 (LOM = 16 years)							
Variable	**Unit**	**VDM 01**	**VDM 02**	**VDM 03**	**VDM 04**	**VDM 05**	**VDM 06**
DVC TDABC	million R	7,824.34	8,355.93	8,627.17	8,671.89	8,671.89	3,584.17
NPV TDABC	million R	2,495.62	2,329.92	2,225.42	2,148.77	2,148.77	3,433.34

From Table 3-14 it can be seen that the NPVs are the inverse of the DVCs. Together, VDM 04 and VDM 05 have the highest DVCs (R8,671 million) and the lowest NPVs (R2,184 million); and VDM 06 has the lowest DVC (R3,584 million) and the highest NPV (R3,433 million). Table 3-14 verifies the expectancy that VDM 04 and VDM 05 will have the same DVCs and NPVs.

3.6 Summary

This chapter focused on the optimisation of a hypothetical ore body – a tabular coal deposit. The resource optimisation was done by constructing VDMs. A VDM calculates the value of each block in the block model by applying the following formula:

$$Value\ (for\ each\ individual\ block\ in\ the\ block\ model) = revenue - variable\ mining\ and\ processing\ cost$$

Six VDMs were constructed, each applied a unique set of variable costs (refer to Section 3.3.1 – *VDM construction*). A cut-off value (for each block in the block model) of greater than zero was applied to determine the mineable footprint for each of the VDMs. The VDMs provided six footprints (refer to Figure 3-9, Figure 3-10, Figure 3-11, Figure 3-12, Figure 3-13 and Figure 3-14). In Section 3.1 – *Introduction* it was forecasted that there will be six unique mining footprints. The results yielded five unique mining footprints because VDM 04 and VDM 05 resulted in the same footprint – coincidentally the entire reserve was included in both.

A production schedule was constructed for each of the VDMs' footprints. Because a production schedule is a simulation of the extraction sequence and date of extraction of the blocks in a block model, it provided a simulated flow of material extracted from the ore body in predefined time periods – for this study the ore body was scheduled annually at a target of 2.5 million primary product tonnes per annum. The annualised simulation provided an OPEX and revenue stream that was incorporated in the financial model to calculate the NPV for each VDM's footprint. The production schedules are summarised in Table 3-11.

A financial model was constructed to calculate the free cash flow for each of the six production schedules; the free cash flows enabled the researcher to calculate the NPVs for each of the VDMs. The NPVs provided a common platform upon which the VDMs' footprints could be compared. The aim of the comparison was to identify the variance in the NPV of each of the six cost application methods. Two scenarios were tested in the financial model. The first scenario's variable costs were based on the variable costs that were used to determine each of the VDMs and the second scenario's costs were based, entirely, on TDABC. The reasoning behind testing the two scenarios were due to the statement made by Lind (2001:82) that, the way that ABC tracks the costs and that it is seen, by many authors, as a superior costing technique, ABC provides a more accurate estimation of the NPV. Scenario 01's results are depicted in Table 3-13 and Scenario 02's results are shown in Table 3-14. In Scenario 01 VDM 05 had the highest NPV (R5,651 million) and in Scenario 02 VDM 06 had the highest NPV (R3,433 million). For both scenarios the order of the NPVs was the reverse of the DVCs – a high DVC yielded a low NPV and vice versa.

The next chapter will discuss the overall findings and recommendations from this study. It will include the aims and objectives of the study as well as what the findings were of those objectives by referring back to previous chapters.

CHAPTER 4: CONCLUSION AND RECOMMENDATIONS

4.1 Introduction

As was highlighted in the study, South Africa is a mineral rich country that has depended on the significant contribution that the mining industry makes to its economy for many years. The mining sector continues to show upward trends in its contribution to the GDP, GFCF and exports. In line with this the mining industry employed 2.9% of the economically active population in 2012 which translates to 2.6% of all the workers in the non-agricultural formal sectors of the economy. In 2012 the DMR received 2,705 applications for prospecting rights and 144 for mining rights which alludes to the fact that studies to determine the economic viability of new mines are alive and well.

The process of determining the footprint of the mine is known as resource optimisation. During the optimisation phase costs and prices are applied to the ore body to determine the portions of the ore body that are deemed economical for exploitation. The dilemma in the optimisation process is the manner in which the costs are being applied. All the references found to the capital and operating expense inputs to the optimisation process refer to benchmarked unit costs i.e. Rand per tonne.

The researcher is of the opinion that benchmarked unit costs could over or under estimate the value of a mining project. The reason for this is because, inevitably, no one resource will have the same geology and every mine's operations are unique. With varying geology the variable costs will also vary. Therefore, the application of a single benchmarked unit cost is nonsensical. The proposed costing alternative which was investigated in this study is the application of TDABC. The manner in which TDABC is calculated will ensure that the applied costs will vary according to the variance in the geology across the resource. Also, the costs will use equipment specific data obtained from OEMs.

In context of the aforementioned the primary research problem which was investigated in this study was to determine whether the application of TDABC for the variable costs during the resource optimisation phase will yield different results to the current practice of applying benchmarked unit costs (refer to Section 1.5 – *Research problem and objectives*). Therefore, the primary objective of this study was to determine the effect of applying TDABC for the variable costs during the resource optimisation phase instead of the conventional benchmarked unit costs.

In support of the primary objective three specific objectives were identified (refer to Section 1.5 – *Research problem and objectives*):

- To define a hypothetical ore body that can be readied for the optimisation process.

- To conduct the resource optimisation process on the ore body to define the economic footprint(s) by applying the different costs (benchmarked unit costs vs TDABC).
- To compare the NPV of each of the economic footprints by means of a financial model.

4.2 Synopsys

4.2.1 Activity-Based Costing

Robin Cooper and Robert Kaplan introduced ABC in the late 1980s. In essence ABC is a managerial costing tool that is more expensive than traditional costing techniques and not required for external financial reporting. Consequently, ABC should only be implemented if the costs are offset by the expected benefit. The research done during this study has indicated that ABC is still a useful management tool. An in-depth literature review revealed that ABC is a more appropriate costing method for OPEX than traditional costing.

ABC has one purpose – to assist in managerial decision making. ABC assigns costs to activities and then to services and products. ABC enables the manager to manage costs by modifying the activities used to produce the service or product.

A shortfall of ABC is that the maintenance of the ABC system can be costly, especially if the system uses many activity cost drivers. TDABC was introduced as an alternative to the traditional ABC system. TDABC addresses the limitations posed by ABC: it is simpler, less costly, faster to implement and allows activity cost driver rates to be based on the practical capacity of resources supplied.

4.2.2 Mining resource optimisation

As a result of the complexity of a mining project, a project can have varying values depending on the extent to which the project has been optimised. During the optimisation phase numerous assumptions have to be made regarding the: geology; geotechnical parameters; costs and commodity prices.

The process that is followed to derive a strategic mine plan incorporates the resource optimisation process. Resource optimisation's sole purpose is to define the optimal mining footprint, given the prevailing economic and physical parameters. In essence, the aim of the optimisation process is to maximise the inventory that is deemed economical for exploitation.

The prevailing cost application method during resource optimisation sees the application of benchmarked unit costs. Costs are used for the budget forecasts of organisations, therefore it is crucial that the way in which mining systems are costed should be reviewed and understood.

Incorrect costing could result in the wrongful implementation of marginal projects that will result in losses for the organisation.

Lind (2001:82) compared ABC with traditional costing when estimating the costs of a mining project. Lind argued that, the way that ABC tracks the costs and that it is seen, by many authors, as a superior costing technique, it provides a better estimation of the costs than traditional costing techniques.

4.2.3 Case study

To investigate the effect that the cost application method can have on the resource optimisation process, a hypothetical massive tabular coal deposit has been optimised for its economical footprint. To determine the economical footprint of the ore body, VDMs were constructed. In total six VDMs were constructed to compare the difference in the NPVs yielded by the different cost application methods. The variable costs that were applied are:

- VDM 01: used TDABC principles to calculate the variable costs.
- VDM 02: the total costs obtained from VDM 01 were recalculated to unit costs.
- VDM 03: the grand total cost obtained in VDM 01 was recalculated to a single unit cost.
- VDM 04: Wood MacKenzie data, based on export and domestic product tonnes, for a similar mine was used to calculate the variable costs.
- VDM 05: Wood MacKenzie data, based on total product tonnes, for a similar mine was used to calculate the variable costs.
- VDM 06: Benchmark data for a similar mine was used to calculate the variable costs.

Each, except VDM 04 and VDM 05, of the VDMs yielded a unique LOM and total ROM tonnes because of the varying footprints that were obtained (refer to Table 3-11). VDM 04 and VDM 05 had the same footprints because the costs were such that all the blocks in the block model had positive values, therefore, the VDMs encapsulated the entire reserve. The different footprints directly impact the production scheduling – the ore mined in a given year are not necessarily the same (refer to Section 3.4 – *Production scheduling*). Because of the production schedules that vary, the annual variable cost profiles vary for each of the production schedules. The result is that, for each unique footprint, unique NPVs were obtained.

The NPVs were calculated by means of a financial model. The NPVs provided a common platform upon which the VDMs' footprints could be compared. The aim of the comparison was to identify the variance in the NPV of each of the six cost application methods. Two scenarios were tested in the financial model. The first scenario's variable costs were based on the variable costs that were used to determine each of the VDMs and the second scenario's costs were based, entirely,

on TDABC. Hence, the financial model was constructed to calculate two NPVs for each VDM (footprint) (refer to Section 3.5.2 – *Financial model construction*). The results of the NPVs are available in Table 3-13 and Table 3-14; in Scenario 01 VDM 05 had the highest NPV (R5,651 million) and in Scenario 02 VDM 06 had the highest NPV (R3,433 million).

To grasp the behaviour of the variable costs and NPVs over time, discounted variable cost graphs and discounted free cash flow (NPV) graphs were constructed for each free cash flow (refer to Figure 3-21, Figure 3-22, Figure 3-23 and Figure 3-24). In all 12 NPVs that were calculated the order of the NPVs were the reverse of the order of the DVCs; in other words a high DVC yielded a low NPV and vice versa. The results showed no correlation between the NPVs of Scenario 01 and Scenario 02.

4.3 Research objectives – results

The primary objective of this study was to determine the effect of applying TDABC for the variable costs, as opposed to benchmarked unit costs, during the resource optimisation phase, on the NPV of a mining project.

From the results (refer to Section 3.5.3 – *Financial model results*) it is clear that the method of variable cost application has a major impact on the NPV of a mining project. The NPVs obtained in both scenarios ranged between R2,148 million (Scenario 02 VDM 04 and VDM 05) to as much as R5,651 million (Scenario 01 VDM 05). The only varying factor was the different method of applying (calculating) the variable costs during the resource optimisation phase and in the free cash flow calculation.

Three secondary objectives were identified to support the primary objective:

- A hypothetical ore deposit that formed the basis of the case study was defined; the geological to mining model conversion was conducted on the deposit that readied the model for the resource optimisation process. The ore deposit that was created is a massive tabular coal deposit (refer to Section 3.2 – *Geological resource*). The model contains 101 Mt GTIS that is reduced to 91 million MTIS and 90 million ROM tonnes when the modifying factors shown in Table 3-1 are applied. The 90 million ROM tonnes are made up of 35 million tonne export product, 10 million tonne domestic product and 45 million tonne discards.
- The ore deposit was optimised to determine the economical footprints of the resource by constructing value distribution models with different variable cost inputs. In total 6 footprints were obtained from the optimisation process (refer to Section 3.3.2 – *Value Distribution Models' results*). Two of the footprints are identical due to the behaviour of the variable costs that were applied to each (refer to Figure 3-13 and Figure 3-14).

- The NPV of each of the footprints were calculated by means of a financial model (refer to Section 3.5 – *Financial model*) based on the production schedule that was constructed for each footprint (refer to Section 3.4 – *Production scheduling*). Section 3.5.3 – *Financial model results* shows that in each case the NPVs obtained are the reverse of the DVCs (refer to Figure 3-21, Figure 3-22, Figure 3-23 and Figure 3-24), i.e. a high DVC yields a low NPV and vice versa.

4.4 Recommendations

When the NPVs of the two scenarios (refer to Table 3-13 and Table 3-14) are compared, it is clear that the variable costs applied during the resource optimisation phase have a great impact on the NPV that the project yields. The NPVs obtained when TDABC principles are used to calculate the variable costs for each of the six footprints vary considerably (refer to Table 3-14). Considering Lind's (2001:82) conclusion when he compared ABC with traditional costing when estimating the costs of a mining project – Lind argued that the way that ABC tracks the costs and that it is seen, by many authors, as a superior costing technique, it provides a better estimation of the costs than traditional costing techniques – ABC should be applied for the variable cost component during resource optimisation.

The question arises – why then does VDM 01 not yield the better NPV? The answer lies in the cut-off value of zero that was applied for the resource optimisation (refer to Section 3.3 – *Economical footprint*). It was decided that blocks with a value of zero and less would be excluded from the economical footprint – this assumption is sub-optimal. This is proven by the fact that in Scenario 02 VDM 06 has the highest NPV (Table 3-14) but the smallest ROM tonnes (refer to Table 3-11).

Based on the above it is recommended that TDABC be used for the variable cost component of the resource optimisation phase. It is, however, necessary to apply different cut-off values (zero and less has proven to be sub-optimal) to obtain multiple footprints. Each footprint should then be evaluated in a financial model for its NPV. The cut-off value that yields the highest NPV is the optimum economical footprint, given the set of economical and physical parameters that have been assumed.

4.5 Limitations of the study

The following limitations apply to the study:

- This study assumed single values for the variable inputs like commodity prices, diesel costs and equipment operating costs. The resource optimisation phase (economic footprint calculation) and NPV are highly dependent on these assumptions. A sensitivity

analysis should be done to determine which of the variables have the greatest impact. The input values of these variables varied during resource optimisation and financial modelling.

- The ore body that was used for the study is in a two dimensional block model. A VDM can only be constructed for a two dimensional block model. When a three dimensional block model is optimised an optimiser such at Geovia's Whittle software package should be used that will apply the LG algorithm.
- The fixed costs applied in this study does not cater for a change in capacity, i.e. there is no increase in the level of activity that will cause a step in the fixed cost (refer to Figure 2-1). In reality a mine will be optimised for different capacities, for example 1 million tonne primary product per annum, 1.5 million tonne primary product per annum, 2 million tonne primary product per annum and so forth. This will, inevitably, result in a step change in the fixed costs.

4.6 Recommendations for further research

This study leaves the following opportunities for further research:

- The study can be replicated on a three dimensional block model to determine whether the manner in which the costs behave is similar.
- It can be investigated how the CAPEX can be included in the resource optimisation phase and whether the inclusion of the CAPEX during resource optimisation will result in a better NPV than when it is only included in the financial model.
- The study can be replicated with different cut-off values during the resource optimisation phase (refer to Section 3.3 – *Economical footprint*). In doing so the footprint can be calculated that will yield the greatest NPV. VDM 06 resulted in the greatest NPV in this study when TDABC principles are applied (refer to Table 3-14); VDM 06 also exploited the smallest portion of the reserve (refer to Table 3-11). It is possible that the optimum footprint could be greater or smaller than that of VDM 06.

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APPENDIX A: VDM 01 SCENARIO 01 AND SCENARIO 02 NPV CALCULATIONS

VDM01 - NPV Scenario 01 and Scenario 02												
Year			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Unit	**Value**										
sc_rom_cont				**7,856,101**	**7,337,431**	**6,020,333**	**5,635,972**	**6,017,013**	**6,690,457**	**6,896,763**	**6,664,933**	**6,621,963**
Total Revenue				**2,241,566,837**	**2,221,269,734**	**2,151,927,132**	**2,137,633,184**	**2,155,581,561**	**2,168,598,275**	**2,173,932,278**	**2,161,533,817**	**2,154,675,758**
revenue_prim				2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000
revenue_sec				241,566,837	221,269,734	151,927,132	137,633,184	155,581,561	168,598,276	173,932,278	161,533,817	154,675,758
revenue_total				2,241,566,837	2,221,269,734	2,151,927,132	2,137,633,184	2,155,581,561	2,168,598,275	2,173,932,278	2,161,533,817	2,154,675,758
Total operating cash cost				**1,278,913,257**	**1,385,678,565**	**1,870,280,108**	**2,035,136,268**	**2,192,741,026**	**1,826,728,454**	**1,589,245,768**	**1,535,923,678**	**1,494,199,769**
VDM01: Variable cost - mining and processing				833,105,240	945,666,160	1,445,518,962	1,614,647,550	1,767,903,448	1,394,765,935	1,155,060,171	1,104,428,332	1,063,339,866
truck_diesel_total				12,109,998	15,654,711	15,904,899	16,496,032	19,662,146	19,543,533	16,310,473	12,279,244	7,413,199
truck_opex				27,345,157	35,349,348	35,914,289	37,249,104	44,398,394	44,130,558	36,830,100	27,727,325	16,739,482
truck_labour_cost				1,171,935	1,514,972	1,539,184	1,596,390	1,902,788	1,891,310	1,578,433	1,188,314	717,406
truck_total_cost				40,627,091	52,519,032	53,358,372	55,341,527	65,963,328	65,565,401	54,719,005	41,194,883	24,870,087
shovel_diesel_cost				19,409,191	18,127,772	14,873,764	13,924,167	14,865,562	16,529,365	17,039,061	16,466,305	16,360,144
shovel_labour_cost				554,548	517,936	424,965	397,833	424,730	472,268	486,830	470,466	467,433
shovel_opex_cost				25,878,921	24,170,362	19,831,686	18,565,556	19,820,749	22,039,153	22,718,748	21,955,074	21,813,525
shovel_total_cost				45,842,661	42,816,070	35,130,415	32,887,556	35,111,041	39,040,785	40,244,640	38,891,845	38,641,101
dozer_diesel_cost				130,155,948	223,372,219	615,653,383	744,440,593	818,359,783	540,301,123	380,502,857	368,219,268	354,343,403
dozer_opex_cost				66,209,765	113,628,477	313,180,199	378,693,693	416,296,064	274,848,832	193,560,149	187,311,541	180,252,948
dozer_labour_cost				3,395,373	5,827,101	16,060,523	19,420,189	21,348,516	14,094,812	9,926,161	9,605,720	9,243,741
dozer_total_cost				199,761,085	342,827,797	944,894,105	1,142,554,476	1,256,004,363	829,244,767	583,989,167	565,136,529	543,840,092
debush_cost				7,584,470	5,997,241	5,363,975	5,142,656	4,552,503	4,674,557	4,651,256	4,410,444	3,971,296
proc_opex_cost				475,418,883	444,031,122	364,325,766	341,065,830	364,124,849	404,878,905	417,363,679	403,334,302	400,733,920
proc_disc_cost				63,871,051	57,474,898	42,446,330	37,655,504	42,147,363	51,361,519	54,092,424	51,460,328	51,283,370
proc_cost				539,289,934	501,506,020	406,772,095	378,721,335	406,272,213	456,240,424	471,456,103	454,794,630	452,017,290
cost_total				833,105,240	945,666,160	1,445,518,962	1,614,647,550	1,767,903,448	1,394,765,935	1,155,060,171	1,104,428,332	1,063,339,866
Mining costs - fixed	R	100,000,000		100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000
Processing costs - fixed	R	200,000,000		200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000
Logistic costs	R/ROMt	10		78,561,012	73,374,314	60,203,332	56,359,723	60,170,131	66,904,571	68,967,628	66,649,332	66,219,629
Total operating cash costs - excl. royalties				1,211,666,252	1,319,040,473	1,805,722,294	1,971,007,273	2,128,073,579	1,761,670,506	1,524,027,799	1,471,077,664	1,429,559,496
Royalties	%	3		67,247,005	66,638,092	64,557,814	64,128,996	64,667,447	65,057,948	65,217,968	64,846,015	64,640,273
Total operating cash cost	**R**			**1,278,913,257**	**1,385,678,565**	**1,870,280,108**	**2,035,136,268**	**2,192,741,026**	**1,826,728,454**	**1,589,245,768**	**1,535,923,678**	**1,494,199,769**
EBITDA				**962,653,580**	**835,591,169**	**281,647,024**	**102,496,915**	**-37,159,465**	**341,869,821**	**584,686,510**	**625,610,139**	**660,475,990**
Depreciation - zero (contractor operation)	%	-	-	-	-	-	-	-	-	-	-	-
EBIT				**962,653,580**	**835,591,169**	**281,647,024**	**102,496,915**	**-37,159,465**	**341,869,821**	**584,686,510**	**625,610,139**	**660,475,990**
Total CAPEX			**50,000,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	R	50,000,000	50,000,000	-	-	-	-	-	-	-	-	-
Sustainable CAPEX - zero (contractor operation)	R	-	-	-	-	-	-	-	-	-	-	-
DCF			**-50,000,000**	**563,716,061**	**440,819,950**	**133,859,620**	**43,886,630**	**-22,052,334**	**118,805,419**	**183,052,464**	**176,454,730**	**167,827,676**

Year			1	2	3	4	5	6	7	8	9	10
EBIT			-	962,653,580	835,591,169	281,647,024	102,496,915	-37,159,465	341,869,821	584,686,510	625,610,139	660,475,990
-tax			-	336,928,753	292,456,909	98,576,458	35,873,920	-	119,654,437	204,640,279	218,963,549	231,166,596
+depreciation			-	-	-	-	-	-	-	-	-	-
-change in working capital												
-capex			50,000,000	-	-	-	-	-	-	-	-	-
Free cash flow			-50,000,000	625,724,827	543,134,260	183,070,565	66,622,995	-37,159,465	222,215,384	380,046,232	406,646,590	429,309,393
Discount factor	%	11.00	1.00	0.90	0.81	0.73	0.66	0.59	0.53	0.48	0.43	0.39
Discounted free cash flow			-50,000,000	563,716,061	440,819,950	133,859,620	43,886,630	-22,052,334	118,805,419	183,052,464	176,454,730	167,827,676
NPV	R	2,495,621,310										

VDM01 - NPV Scenario 01 and Scenario 02							
Year	**11**	**12**	**13**	**14**	**15**	**16**	**17**
sc_rom_cont	**6,567,617**	**6,300,650**	**5,657,500**	**5,544,480**	**996,234**	**-**	**-**
Total Revenue	**2,147,395,790**	**2,142,450,152**	**2,117,981,056**	**2,097,192,194**	**385,553,071**	**-**	**-**
revenue_prim	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	373,255,533	-	-
revenue_sec	147,395,790	142,450,152	117,981,056	97,192,194	12,297,538	-	-
revenue_total	2,147,395,790	2,142,450,152	2,117,981,056	2,097,192,194	385,553,071	-	-
Total operating cash cost	**1,360,652,303**	**1,212,647,495**	**1,083,647,938**	**999,110,108**	**422,555,592**	**-**	**-**
VDM01: Variable cost - mining and processing	930,554,263	785,367,486	663,533,506	580,749,543	101,026,664	-	-
truck_diesel_total	1,717,753	3,343,975	7,225,915	9,276,154	3,097,831	-	-
truck_opex	3,878,797	7,550,911	16,316,583	20,946,153	6,995,102	-	-
truck_labour_cost	166,234	323,610	699,282	897,692	299,790	-	-
truck_total_cost	5,762,783	11,218,497	24,241,780	31,119,999	10,392,723	-	-
shovel_diesel_cost	16,225,876	15,566,313	13,977,353	13,698,127	2,461,283	-	-
shovel_labour_cost	463,596	444,752	399,353	391,375	70,322	-	-
shovel_opex_cost	21,634,502	20,755,083	18,636,471	18,264,169	3,281,711	-	-
shovel_total_cost	38,323,975	36,766,148	33,013,177	32,353,671	5,813,316	-	-
dozer_diesel_cost	282,947,981	198,824,076	144,128,933	90,739,800	10,938,845	-	-
dozer_opex_cost	143,934,408	101,140,943	73,317,762	46,158,942	5,564,543	-	-
dozer_labour_cost	7,381,252	5,186,715	3,759,885	2,367,125	285,361	-	-
dozer_total_cost	434,263,641	305,151,734	221,206,580	139,265,866	16,788,749	-	-
debush_cost	3,794,221	3,644,456	3,385,032	3,440,462	637,430	-	-
proc_opex_cost	397,445,107	381,289,406	342,368,599	335,529,086	60,287,953	-	-
proc_disc_cost	50,964,537	47,297,245	39,318,338	39,040,458	7,106,494	-	-
proc_cost	448,409,643	428,586,651	381,686,937	374,569,544	67,394,447	-	-
cost_total	930,554,263	785,367,486	663,533,506	580,749,543	101,026,664	-	-
Mining costs - fixed	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	-	-
Processing costs - fixed	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	-	-
Logistic costs	65,676,166	63,006,503	56,575,000	55,444,799	9,962,336	-	-
Total operating cash costs - excl. royalties	1,296,230,429	1,148,373,990	1,020,108,506	936,194,342	410,989,000	-	-
Royalties	64,421,874	64,273,505	63,539,432	62,915,766	11,566,592	-	-
Total operating cash cost	**1,360,652,303**	**1,212,647,495**	**1,083,647,938**	**999,110,108**	**422,555,592**	**-**	**-**
EBITDA	**786,743,487**	**929,802,657**	**1,034,333,118**	**1,098,082,086**	**-37,002,521**	**-**	**-**
Depreciation - zero (contractor operation)	-	-	-	-	-	-	-
EBIT	**786,743,487**	**929,802,657**	**1,034,333,118**	**1,098,082,086**	**-37,002,521**	**-**	**-**
Total CAPEX	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	-	-	-	-	-	-	-
Sustainable CAPEX - zero (contractor operation)	-	-	-	-	-	-	-
DCF	**180,101,249**	**191,757,065**	**192,175,510**	**183,801,664**	**-8,584,393**	**-**	**-**

Year	11	12	13	14	15	16	17
EBIT	786,743,487	929,802,657	1,034,333,118	1,098,082,086	-37,002,521	-	-
-tax	275,360,220	325,430,930	362,016,591	384,328,730	-	-	-
+depreciation	-	-	-	-	-	-	-
-change in working capital							
-capex	-	-	-	-	-	-	-
Free cash flow	511,383,267	604,371,727	672,316,527	713,753,356	-37,002,521	-	-
Discount factor	0.35	0.32	0.29	0.26	0.23	0.21	0.19
Discounted free cash flow	180,101,249	191,757,065	192,175,510	183,801,664	-8,584,393	-	-
NPV							

APPENDIX B: VDM 02 SCENARIO 01 AND SCENARIO 02 NPV CALCULATIONS

VDM02 - NPV Scenario 01												
Year			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Unit	**Value**										
sc_rom_cont				**7,796,355**	**7,231,793**	**6,131,562**	**5,656,303**	**5,913,990**	**6,549,131**	**7,029,334**	**6,707,555**	**6,643,563**
Total Revenue				**2,240,198,844**	**2,214,719,822**	**2,157,286,742**	**2,137,739,335**	**2,151,323,371**	**2,167,483,101**	**2,178,133,112**	**2,164,855,356**	**2,156,711,488**
revenue_prim				2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000
revenue_sec				240,198,844	214,719,822	157,286,742	137,739,336	151,323,371	167,483,101	178,133,112	164,855,356	156,711,488
revenue_total				2,240,198,844	2,214,719,822	2,157,286,742	2,137,739,335	2,151,323,371	2,167,483,101	2,178,133,112	2,164,855,356	2,156,711,488
Total operating cash cost				**1,375,051,848**	**1,538,523,866**	**1,848,412,367**	**1,918,227,079**	**2,067,922,923**	**1,972,414,885**	**1,725,768,813**	**1,602,284,727**	**1,551,321,316**
VDM02: Variable cost - mining and processing				929,882,330	1,099,764,345	1,422,378,145	1,497,531,868	1,644,243,318	1,541,899,079	1,290,131,476	1,170,263,521	1,120,184,346
vdm02_truck_cost				49,350,929	45,777,247	38,812,787	35,804,399	37,435,559	41,456,001	44,495,687	42,458,821	42,053,751
vdm02_shovel_cost				45,530,715	42,233,669	35,808,322	33,032,811	34,537,704	38,246,927	41,051,313	39,172,119	38,798,405
vdm02_dozer_cost				297,309,838	513,922,781	925,290,180	1,038,829,535	1,165,333,424	1,012,194,215	721,693,474	627,916,506	583,180,021
vdm02_debush_cost				7,460,724	5,996,431	5,459,327	5,179,943	4,726,142	4,595,512	4,825,967	4,535,286	4,323,483
vdm02_proc_cost				530,230,124	491,834,217	417,007,529	384,685,179	402,210,488	445,406,423	478,065,034	456,180,789	451,828,686
vdm02_total_cost				929,882,330	1,099,764,345	1,422,378,145	1,497,531,868	1,644,243,318	1,541,899,079	1,290,131,476	1,170,263,521	1,120,184,346
Mining costs - fixed	R	100,000,000		100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000
Processing costs - fixed	R	200,000,000		200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000
Logistic costs	R/ROMt	10		77,963,553	72,317,926	61,315,620	56,563,032	59,139,904	65,491,314	70,293,344	67,075,546	66,435,625
Total operating cash costs - excl. royalties				1,307,845,883	1,472,082,272	1,783,693,765	1,854,094,899	2,003,383,222	1,907,390,392	1,660,424,820	1,537,339,067	1,486,619,971
Royalties	%	3		67,205,965	66,441,595	64,718,602	64,132,180	64,539,701	65,024,493	65,343,993	64,945,661	64,701,345
Total operating cash cost	**R**			**1,375,051,848**	**1,538,523,866**	**1,848,412,367**	**1,918,227,079**	**2,067,922,923**	**1,972,414,885**	**1,725,768,813**	**1,602,284,727**	**1,551,321,316**
EBITDA				**865,146,996**	**676,195,956**	**308,874,375**	**219,512,256**	**83,400,448**	**195,068,216**	**452,364,299**	**562,570,629**	**605,390,172**
Depreciation - zero (contractor operation)	%	-	-	-	-	-	-	-	-	-	-	-
EBIT				**865,146,996**	**676,195,956**	**308,874,375**	**219,512,256**	**83,400,448**	**195,068,216**	**452,364,299**	**562,570,629**	**605,390,172**
Total CAPEX			**50,000,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	R	50,000,000	50,000,000	-	-	-	-	-	-	-	-	-
Sustainable CAPEX - zero (contractor operation)	R	-	-	-	-	-	-	-	-	-	-	-
DCF			**-50,000,000**	**506,617,610**	**356,730,274**	**146,800,083**	**93,989,689**	**32,171,169**	**67,789,432**	**141,625,295**	**158,674,296**	**153,830,309**
EBIT			-	865,146,996	676,195,956	308,874,375	219,512,256	83,400,448	195,068,216	452,364,299	562,570,629	605,390,172
-tax			-	302,801,449	236,668,584	108,106,031	76,829,290	29,190,157	68,273,875	158,327,505	196,899,720	211,886,560
+depreciation			-	-	-	-	-	-	-	-	-	-
-change in working capital												
-capex			50,000,000	-	-	-	-	-	-	-	-	-
Free cash flow			-50,000,000	562,345,547	439,527,371	200,768,344	142,682,966	54,210,291	126,794,340	294,036,794	365,670,909	393,503,612
Discount factor	%	11.00	1.00	0.90	0.81	0.73	0.66	0.59	0.53	0.48	0.43	0.39
Discounted free cash flow			-50,000,000	506,617,610	356,730,274	146,800,083	93,989,689	32,171,169	67,789,432	141,625,295	158,674,296	153,830,309
NPV	R	2,386,613,815										

VDM02 - NPV Scenario 01							
Year	**11**	**12**	**13**	**14**	**15**	**16**	**17**
sc_rom_cont	**6,569,837**	**6,569,550**	**5,986,904**	**5,581,313**	**4,184,131**	**-**	**-**
Total Revenue	**2,150,101,833**	**2,148,578,223**	**2,131,391,437**	**2,110,676,736**	**1,589,566,956**	**-**	**-**
revenue_prim	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	1,524,442,227	-	-
revenue_sec	150,101,833	148,578,223	131,391,437	110,676,736	65,124,729	-	-
revenue_total	2,150,101,833	2,148,578,223	2,131,391,437	2,110,676,736	1,589,566,956	-	-
Total operating cash cost	**1,464,697,234**	**1,344,173,506**	**1,192,983,073**	**1,100,547,699**	**845,820,662**	**-**	**-**
VDM02: Variable cost - mining and processing	1,034,495,814	914,020,656	769,172,286	681,414,263	456,292,339	-	-
vdm02_truck_cost	41,587,065	41,585,253	37,897,105	35,329,713	26,485,552	-	-
vdm02_shovel_cost	38,367,845	38,366,174	34,963,522	32,594,870	24,435,328	-	-
vdm02_dozer_cost	503,854,352	383,501,779	285,630,158	230,524,260	118,173,224	-	-
vdm02_debush_cost	3,871,968	3,772,333	3,512,133	3,380,299	2,635,451	-	-
vdm02_proc_cost	446,814,583	446,795,116	407,169,368	379,585,121	284,562,783	-	-
vdm02_total_cost	1,034,495,814	914,020,656	769,172,286	681,414,263	456,292,339	-	-
Mining costs - fixed	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	-	-
Processing costs - fixed	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	-	-
Logistic costs	65,698,365	65,695,503	59,869,044	55,813,133	41,841,315	-	-
Total operating cash costs - excl. royalties	1,400,194,179	1,279,716,159	1,129,041,330	1,037,227,397	798,133,654	-	-
Royalties	64,503,055	64,457,347	63,941,743	63,320,302	47,687,009	-	-
Total operating cash cost	**1,464,697,234**	**1,344,173,506**	**1,192,983,073**	**1,100,547,699**	**845,820,662**	**-**	**-**
EBITDA	**685,404,599**	**804,404,717**	**938,408,364**	**1,010,129,038**	**743,746,294**	**-**	**-**
Depreciation - zero (contractor operation)	-	-	-	-	-	-	-
EBIT	**685,404,599**	**804,404,717**	**938,408,364**	**1,010,129,038**	**743,746,294**	**-**	**-**
Total CAPEX	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	-	-	-	-	-	-	-
Sustainable CAPEX - zero (contractor operation)	-	-	-	-	-	-	-
DCF	**156,902,760**	**165,895,726**	**174,353,023**	**169,079,708**	**112,154,439**	**-**	**-**
EBIT	685,404,599	804,404,717	938,408,364	1,010,129,038	743,746,294	-	-
-tax	239,891,610	281,541,651	328,442,927	353,545,163	260,311,203	-	-
+depreciation	-	-	-	-	-	-	-
-change in working capital							
-capex	-	-	-	-	-	-	-
Free cash flow	445,512,990	522,863,066	609,965,437	656,583,874	483,435,091	-	-
Discount factor	0.35	0.32	0.29	0.26	0.23	0.21	0.19
Discounted free cash flow	156,902,760	165,895,726	174,353,023	169,079,708	112,154,439	-	-
NPV							

VDM02 - NPV Scenario 02												
Year			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Unit	**Value**										
sc_rom_cont				**7,796,355**	**7,231,793**	**6,131,562**	**5,656,303**	**5,913,990**	**6,549,131**	**7,029,334**	**6,707,555**	**6,643,563**
Total Revenue				**2,240,198,844**	**2,214,719,822**	**2,157,286,742**	**2,137,739,335**	**2,151,323,371**	**2,167,483,101**	**2,178,133,112**	**2,164,855,356**	**2,156,711,488**
revenue_prim				2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000
revenue_sec				240,198,844	214,719,822	157,286,742	137,739,336	151,323,371	167,483,101	178,133,112	164,855,356	156,711,488
revenue_total				2,240,198,844	2,214,719,822	2,157,286,742	2,137,739,335	2,151,323,371	2,167,483,101	2,178,133,112	2,164,855,356	2,156,711,488
Total operating cash cost				**1,270,015,179**	**1,511,591,902**	**1,902,105,065**	**1,997,913,460**	**2,185,430,647**	**2,073,257,219**	**1,769,391,173**	**1,622,928,771**	**1,553,618,080**
VDM02: Variable cost - mining and processing				824,845,661	1,072,832,381	1,476,070,843	1,577,218,248	1,761,751,042	1,642,741,412	1,333,753,835	1,190,907,564	1,122,481,110
vdm02_total_cost				824,845,661	1,072,832,381	1,476,070,843	1,577,218,248	1,761,751,042	1,642,741,412	1,333,753,835	1,190,907,564	1,122,481,110
Mining costs - fixed	R	100,000,000		100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000
Processing costs - fixed	R	200,000,000		200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000
Logistic costs	R/ROMt	10		77,963,553	72,317,926	61,315,620	56,563,032	59,139,904	65,491,314	70,293,344	67,075,546	66,435,625
Total operating cash costs - excl. royalties				1,202,809,214	1,445,150,307	1,837,386,463	1,933,781,280	2,120,890,946	2,008,232,726	1,704,047,180	1,557,983,110	1,488,916,735
Royalties	%	3		67,205,965	66,441,595	64,718,602	64,132,180	64,539,701	65,024,493	65,343,993	64,945,661	64,701,345
Total operating cash cost	**R**			**1,270,015,179**	**1,511,591,902**	**1,902,105,065**	**1,997,913,460**	**2,185,430,647**	**2,073,257,219**	**1,769,391,173**	**1,622,928,771**	**1,553,618,080**
EBITDA				**970,183,665**	**703,127,920**	**255,181,677**	**139,825,876**	**-34,107,276**	**94,225,882**	**408,741,939**	**541,926,586**	**603,093,408**
Depreciation - zero (contractor operation)	%	-	-	-	-	-	-	-	-	-	-	-
EBIT				**970,183,665**	**703,127,920**	**255,181,677**	**139,825,876**	**-34,107,276**	**94,225,882**	**408,741,939**	**541,926,586**	**603,093,408**
Total CAPEX			**50,000,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	R	50,000,000	50,000,000	-	-	-	-	-	-	-	-	-
Sustainable CAPEX - zero (contractor operation)	R	-	-	-	-	-	-	-	-	-	-	-
DCF			**-50,000,000**	**568,125,570**	**370,938,356**	**121,281,318**	**59,869,963**	**-20,241,008**	**32,745,053**	**127,968,095**	**152,851,598**	**153,246,699**
EBIT			-	970,183,665	703,127,920	255,181,677	139,825,876	-34,107,276	94,225,882	408,741,939	541,926,586	603,093,408
-tax			-	339,564,283	246,094,772	89,313,587	48,939,056	-	32,979,059	143,059,679	189,674,305	211,082,693
+depreciation			-	-	-	-	-	-	-	-	-	-
-change in working capital												
-capex			50,000,000	-	-	-	-	-	-	-	-	-
Free cash flow			-50,000,000	630,619,382	457,033,148	165,868,090	90,886,819	-34,107,276	61,246,823	265,682,261	352,252,281	392,010,715
Discount factor	%	11.00	1.00	0.90	0.81	0.73	0.66	0.59	0.53	0.48	0.43	0.39
Discounted free cash flow			-50,000,000	568,125,570	370,938,356	121,281,318	59,869,963	-20,241,008	32,745,053	127,968,095	152,851,598	153,246,699
NPV	R	2,329,921,475										

VDM02 - NPV Scenario 02							
Year	**11**	**12**	**13**	**14**	**15**	**16**	**17**
sc_rom_cont	**6,569,837**	**6,569,550**	**5,986,904**	**5,581,313**	**4,184,131**	**-**	**-**
Total Revenue	**2,150,101,833**	**2,148,578,223**	**2,131,391,437**	**2,110,676,736**	**1,589,566,956**	**-**	**-**
revenue_prim	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	1,524,442,227	-	-
revenue_sec	150,101,833	148,578,223	131,391,437	110,676,736	65,124,729	-	-
revenue_total	2,150,101,833	2,148,578,223	2,131,391,437	2,110,676,736	1,589,566,956	-	-
Total operating cash cost	**1,446,734,899**	**1,295,242,813**	**1,149,598,860**	**1,055,939,444**	**812,532,761**	**-**	**-**
VDM02: Variable cost - mining and processing	1,016,533,479	865,089,964	725,788,073	636,806,009	423,004,438	-	-
vdm02_total_cost	1,016,533,479	865,089,964	725,788,073	636,806,009	423,004,438	-	-
Mining costs - fixed	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	-	-
Processing costs - fixed	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	-	-
Logistic costs	65,698,365	65,695,503	59,869,044	55,813,133	41,841,315	-	-
Total operating cash costs - excl. royalties	1,382,231,844	1,230,785,467	1,085,657,116	992,619,142	764,845,752	-	-
Royalties	64,503,055	64,457,347	63,941,743	63,320,302	47,687,009	-	-
Total operating cash cost	**1,446,734,899**	**1,295,242,813**	**1,149,598,860**	**1,055,939,444**	**812,532,761**	**-**	**-**
EBITDA	**703,366,934**	**853,335,409**	**981,792,578**	**1,054,737,292**	**777,034,195**	**-**	**-**
Depreciation - zero (contractor operation)	-	-	-	-	-	-	-
EBIT	**703,366,934**	**853,335,409**	**981,792,578**	**1,054,737,292**	**777,034,195**	**-**	**-**
Total CAPEX	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	-	-	-	-	-	-	-
Sustainable CAPEX - zero (contractor operation)	-	-	-	-	-	-	-
DCF	**161,014,696**	**175,986,906**	**182,413,659**	**176,546,428**	**117,174,143**	**-**	**-**
EBIT	703,366,934	853,335,409	981,792,578	1,054,737,292	777,034,195	-	-
-tax	246,178,427	298,667,393	343,627,402	369,158,052	271,961,968	-	-
+depreciation	-	-	-	-	-	-	-
-change in working capital							
-capex	-	-	-	-	-	-	-
Free cash flow	457,188,507	554,668,016	638,165,175	685,579,240	505,072,227	-	-
Discount factor	0.35	0.32	0.29	0.26	0.23	0.21	0.19
Discounted free cash flow	161,014,696	175,986,906	182,413,659	176,546,428	117,174,143	-	-
NPV							

APPENDIX C: VDM 03 SCENARIO 01 AND SCENARIO 02 NPV CALCULATIONS

VDM03 - NPV Scenario 01												
Year			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Unit	**Value**										
sc_rom_cont				**7,630,326**	**7,118,007**	**6,396,058**	**5,658,657**	**5,810,802**	**6,401,888**	**7,059,883**	**6,732,594**	**6,647,394**
Total Revenue				**2,234,892,843**	**2,208,177,804**	**2,169,627,541**	**2,137,280,446**	**2,147,066,266**	**2,165,150,577**	**2,178,332,500**	**2,167,529,645**	**2,157,535,007**
revenue_prim				2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000
revenue_sec				234,892,843	208,177,804	169,627,541	137,280,446	147,066,267	165,150,577	178,332,500	167,529,645	157,535,006
revenue_total				2,234,892,843	2,208,177,804	2,169,627,541	2,137,280,446	2,147,066,266	2,165,150,577	2,178,332,500	2,167,529,645	2,157,535,007
Total operating cash cost				**1,737,659,315**	**1,644,831,559**	**1,513,993,565**	**1,380,566,053**	**1,408,188,935**	**1,514,906,408**	**1,633,495,584**	**1,574,381,503**	**1,558,777,410**
VDM03: Variable cost - mining and processing				1,294,309,272	1,207,406,156	1,084,944,158	959,861,066	985,668,926	1,085,933,013	1,197,546,779	1,142,029,677	1,127,577,424
vdm03_cost_tot_cost				1,294,309,272	1,207,406,156	1,084,944,158	959,861,066	985,668,926	1,085,933,013	1,197,546,779	1,142,029,677	1,127,577,424
Mining costs - fixed	R	100,000,000		100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000
Processing costs - fixed	R	200,000,000		200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000
Logistic costs	R/ROMt	10		76,303,258	71,180,069	63,960,582	56,586,573	58,108,021	64,018,878	70,598,830	67,325,937	66,473,935
Total operating cash costs - excl. royalties				1,670,612,530	1,578,586,225	1,448,904,739	1,316,447,639	1,343,776,947	1,449,951,891	1,568,145,609	1,509,355,614	1,494,051,359
Royalties	%	3		67,046,785	66,245,334	65,088,826	64,118,413	64,411,988	64,954,517	65,349,975	65,025,889	64,726,050
Total operating cash cost	**R**			**1,737,659,315**	**1,644,831,559**	**1,513,993,565**	**1,380,566,053**	**1,408,188,935**	**1,514,906,408**	**1,633,495,584**	**1,574,381,503**	**1,558,777,410**
EBITDA				**497,233,528**	**563,346,245**	**655,633,976**	**756,714,393**	**738,877,331**	**650,244,169**	**544,836,916**	**593,148,141**	**598,757,597**
Depreciation - zero (contractor operation)	%	-	-	-	-	-	-	-	-	-	-	-
EBIT				**497,233,528**	**563,346,245**	**655,633,976**	**756,714,393**	**738,877,331**	**650,244,169**	**544,836,916**	**593,148,141**	**598,757,597**
Total CAPEX			**50,000,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	R	50,000,000	50,000,000	-	-	-	-	-	-	-	-	-
Sustainable CAPEX - zero (contractor operation)	R	-	-	-	-	-	-	-	-	-	-	-
DCF			**-50,000,000**	**291,172,787**	**297,195,893**	**311,606,043**	**324,006,286**	**285,017,027**	**225,970,606**	**170,576,434**	**167,298,752**	**152,144,965**
EBIT			-	497,233,528	563,346,245	655,633,976	756,714,393	738,877,331	650,244,169	544,836,916	593,148,141	598,757,597
-tax			-	174,031,735	197,171,186	229,471,891	264,850,038	258,607,066	227,585,459	190,692,920	207,601,849	209,565,159
+depreciation			-	-	-	-	-	-	-	-	-	-
-change in working capital												
-capex			50,000,000	-	-	-	-	-	-	-	-	-
Free cash flow			-50,000,000	323,201,793	366,175,060	426,162,084	491,864,356	480,270,265	422,658,710	354,143,995	385,546,292	389,192,438
Discount factor	%	11.00	1.00	0.90	0.81	0.73	0.66	0.59	0.53	0.48	0.43	0.39
Discounted free cash flow			-50,000,000	291,172,787	297,195,893	311,606,043	324,006,286	285,017,027	225,970,606	170,576,434	167,298,752	152,144,965
NPV	R	2,793,868,809										

VDM03 - NPV Scenario 01							
Year	**11**	**12**	**13**	**14**	**15**	**16**	**17**
sc_rom_cont	**6,598,835**	**6,597,649**	**6,091,031**	**5,648,956**	**5,375,328**	**-**	**-**
Total Revenue	**2,152,453,686**	**2,147,287,265**	**2,135,941,530**	**2,117,034,295**	**2,043,567,422**	**-**	**-**
revenue_prim	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	1,957,169,550	-	-
revenue_sec	152,453,686	147,287,265	135,941,530	117,034,295	86,397,871	-	-
revenue_total	2,152,453,686	2,147,287,265	2,135,941,530	2,117,034,295	2,043,567,422	-	-
Total operating cash cost	**1,549,902,467**	**1,549,534,464**	**1,458,191,828**	**1,378,215,985**	**1,326,861,148**	**-**	**-**
VDM03: Variable cost - mining and processing	1,119,340,510	1,119,139,358	1,033,203,274	958,215,399	911,800,840	-	-
vdm03_cost_tot_cost	1,119,340,510	1,119,139,358	1,033,203,274	958,215,399	911,800,840	-	-
Mining costs - fixed	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	-	-
Processing costs - fixed	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	-	-
Logistic costs	65,988,346	65,976,487	60,910,308	56,489,556	53,753,285	-	-
Total operating cash costs - excl. royalties	1,485,328,856	1,485,115,846	1,394,113,582	1,314,704,956	1,265,554,125	-	-
Royalties	64,573,611	64,418,618	64,078,246	63,511,029	61,307,023	-	-
Total operating cash cost	**1,549,902,467**	**1,549,534,464**	**1,458,191,828**	**1,378,215,985**	**1,326,861,148**	**-**	**-**
EBITDA	**602,551,219**	**597,752,801**	**677,749,702**	**738,818,310**	**716,706,274**	**-**	**-**
Depreciation - zero (contractor operation)	-	-	-	-	-	-	-
EBIT	**602,551,219**	**597,752,801**	**677,749,702**	**738,818,310**	**716,706,274**	**-**	**-**
Total CAPEX	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	-	-	-	-	-	-	-
Sustainable CAPEX - zero (contractor operation)	-	-	-	-	-	-	-
DCF	**137,935,972**	**123,277,043**	**125,923,546**	**123,666,561**	**108,076,895**	**-**	**-**
EBIT	602,551,219	597,752,801	677,749,702	738,818,310	716,706,274	-	-
-tax	210,892,927	209,213,481	237,212,396	258,586,408	250,847,196	-	-
+depreciation	-	-	-	-	-	-	-
-change in working capital							
-capex	-	-	-	-	-	-	-
Free cash flow	391,658,292	388,539,321	440,537,306	480,231,901	465,859,078	-	-
Discount factor	0.35	0.32	0.29	0.26	0.23	0.21	0.19
Discounted free cash flow	137,935,972	123,277,043	125,923,546	123,666,561	108,076,895	-	-
NPV							

VDM03 - NPV Scenario 02												
Year			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Unit	**Value**										
sc_rom_cont				**7,630,326**	**7,118,007**	**6,396,058**	**5,658,657**	**5,810,802**	**6,401,888**	**7,059,883**	**6,732,594**	**6,647,394**
Total Revenue				**2,234,892,843**	**2,208,177,804**	**2,169,627,541**	**2,137,280,446**	**2,147,066,266**	**2,165,150,577**	**2,178,332,500**	**2,167,529,645**	**2,157,535,007**
revenue_prim				2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000
revenue_sec				234,892,843	208,177,804	169,627,541	137,280,446	147,066,267	165,150,577	178,332,500	167,529,645	157,535,006
revenue_total				2,234,892,843	2,208,177,804	2,169,627,541	2,137,280,446	2,147,066,266	2,165,150,577	2,178,332,500	2,167,529,645	2,157,535,007
Total operating cash cost				**1,248,031,727**	**1,772,848,819**	**1,880,292,345**	**1,960,976,104**	**2,148,852,278**	**2,138,834,631**	**1,826,612,087**	**1,634,281,474**	**1,575,555,521**
VDM03: Variable cost - mining and processing				804,681,684	1,335,423,416	1,451,242,937	1,540,271,118	1,726,332,269	1,709,861,236	1,390,663,281	1,201,929,647	1,144,355,536
vdm03_cost_tot_cost				804,681,684	1,335,423,416	1,451,242,937	1,540,271,118	1,726,332,269	1,709,861,236	1,390,663,281	1,201,929,647	1,144,355,536
Mining costs - fixed	R	100,000,000		100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000
Processing costs - fixed	R	200,000,000		200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000
Logistic costs	R/ROMt	10		76,303,258	71,180,069	63,960,582	56,586,573	58,108,021	64,018,878	70,598,830	67,325,937	66,473,935
Total operating cash costs - excl. royalties				1,180,984,941	1,706,603,485	1,815,203,519	1,896,857,691	2,084,440,290	2,073,880,113	1,761,262,112	1,569,255,585	1,510,829,471
Royalties	%	3		67,046,785	66,245,334	65,088,826	64,118,413	64,411,988	64,954,517	65,349,975	65,025,889	64,726,050
Total operating cash cost	**R**			**1,248,031,727**	**1,772,848,819**	**1,880,292,345**	**1,960,976,104**	**2,148,852,278**	**2,138,834,631**	**1,826,612,087**	**1,634,281,474**	**1,575,555,521**
EBITDA				**986,861,116**	**435,328,985**	**289,335,196**	**176,304,342**	**-1,786,012**	**26,315,947**	**351,720,413**	**533,248,171**	**581,979,485**
Depreciation - zero (contractor operation)	%	-	-	-	-	-	-	-	-	-	-	-
EBIT				**986,861,116**	**435,328,985**	**289,335,196**	**176,304,342**	**-1,786,012**	**26,315,947**	**351,720,413**	**533,248,171**	**581,979,485**
Total CAPEX			**50,000,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	R	50,000,000	50,000,000	-	-	-	-	-	-	-	-	-
Sustainable CAPEX - zero (contractor operation)	R	-	-	-	-	-	-	-	-	-	-	-
DCF			**-50,000,000**	**577,891,645**	**229,659,801**	**137,513,611**	**75,489,135**	**-1,059,911**	**9,145,227**	**110,115,912**	**150,403,832**	**147,881,628**
EBIT			-	986,861,116	435,328,985	289,335,196	176,304,342	-1,786,012	26,315,947	351,720,413	533,248,171	581,979,485
-tax			-	345,401,391	152,365,145	101,267,319	61,706,520	-	9,210,581	123,102,145	186,636,860	203,692,820
+depreciation			-	-	-	-	-	-	-	-	-	-
-change in working capital												
-capex			50,000,000	-	-	-	-	-	-	-	-	-
Free cash flow			-50,000,000	641,459,726	282,963,841	188,067,878	114,597,822	-1,786,012	17,105,365	228,618,269	346,611,311	378,286,665
Discount factor	%	11.00	1.00	0.90	0.81	0.73	0.66	0.59	0.53	0.48	0.43	0.39
Discounted free cash flow			-50,000,000	577,891,645	229,659,801	137,513,611	75,489,135	-1,059,911	9,145,227	110,115,912	150,403,832	147,881,628
NPV	R	2,225,422,483										

VDM03 - NPV Scenario 02							
Year	**11**	**12**	**13**	**14**	**15**	**16**	**17**
sc_rom_cont	**6,598,835**	**6,597,649**	**6,091,031**	**5,648,956**	**5,375,328**	**-**	**-**
Total Revenue	**2,152,453,686**	**2,147,287,265**	**2,135,941,530**	**2,117,034,295**	**2,043,567,422**	**-**	**-**
revenue_prim	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	1,957,169,550	-	-
revenue_sec	152,453,686	147,287,265	135,941,530	117,034,295	86,397,871	-	-
revenue_total	2,152,453,686	2,147,287,265	2,135,941,530	2,117,034,295	2,043,567,422	-	-
Total operating cash cost	**1,471,600,255**	**1,346,509,227**	**1,174,665,953**	**1,061,413,971**	**968,762,205**	**-**	**-**
VDM03: Variable cost - mining and processing	1,041,038,299	916,114,122	749,677,399	641,413,386	553,701,898	-	-
vdm03_cost_tot_cost	1,041,038,299	916,114,122	749,677,399	641,413,386	553,701,898	-	-
Mining costs - fixed	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	-	-
Processing costs - fixed	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	-	-
Logistic costs	65,988,346	65,976,487	60,910,308	56,489,556	53,753,285	-	-
Total operating cash costs - excl. royalties	1,407,026,644	1,282,090,609	1,110,587,707	997,902,943	907,455,182	-	-
Royalties	64,573,611	64,418,618	64,078,246	63,511,029	61,307,023	-	-
Total operating cash cost	**1,471,600,255**	**1,346,509,227**	**1,174,665,953**	**1,061,413,971**	**968,762,205**	**-**	**-**
EBITDA	**680,853,431**	**800,778,038**	**961,275,577**	**1,055,620,323**	**1,074,805,217**	**-**	**-**
Depreciation - zero (contractor operation)	-	-	-	-	-	-	-
EBIT	**680,853,431**	**800,778,038**	**961,275,577**	**1,055,620,323**	**1,074,805,217**	**-**	**-**
Total CAPEX	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	-	-	-	-	-	-	-
Sustainable CAPEX - zero (contractor operation)	-	-	-	-	-	-	-
DCF	**155,860,907**	**165,147,781**	**178,601,672**	**176,694,233**	**162,077,011**	**-**	**-**
EBIT	680,853,431	800,778,038	961,275,577	1,055,620,323	1,074,805,217	-	-
-tax	238,298,701	280,272,313	336,446,452	369,467,113	376,181,826	-	-
+depreciation	-	-	-	-	-	-	-
-change in working capital							
-capex	-	-	-	-	-	-	-
Free cash flow	442,554,730	520,505,725	624,829,125	686,153,210	698,623,391	-	-
Discount factor	0.35	0.32	0.29	0.26	0.23	0.21	0.19
Discounted free cash flow	155,860,907	165,147,781	178,601,672	176,694,233	162,077,011	-	-
NPV							

APPENDIX D: VDM 04 SCENARIO 01 AND SCENARIO 02 NPV CALCULATIONS

VDM04 - NPV Scenario 01												
Year			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Unit	**Value**										
sc_rom_cont				**8,061,383**	**7,173,556**	**6,402,125**	**5,664,962**	**5,804,675**	**6,371,034**	**7,036,174**	**6,792,448**	**6,629,313**
Total Revenue				**2,246,863,341**	**2,211,616,619**	**2,169,803,913**	**2,137,001,176**	**2,147,053,801**	**2,163,819,590**	**2,177,155,345**	**2,170,168,740**	**2,156,339,673**
revenue_prim				2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000
revenue_sec				246,863,341	211,616,619	169,803,913	137,001,176	147,053,801	163,819,590	177,155,345	170,168,740	156,339,673
revenue_total				2,246,863,341	2,211,616,619	2,169,803,913	2,137,001,176	2,147,053,801	2,163,819,590	2,177,155,345	2,170,168,740	2,156,339,673
Total operating cash cost				**1,008,967,237**	**981,177,494**	**951,028,772**	**926,056,977**	**932,847,800**	**947,506,995**	**961,313,635**	**955,127,747**	**946,076,468**
VDM04: Variable cost - mining and processing				560,947,503	543,093,436	521,913,400	505,297,323	510,389,434	518,882,069	525,637,235	522,098,202	515,093,151
vdm04_cost_mining_dom				99,497,148	85,291,116	68,438,695	55,217,701	59,269,366	66,026,741	71,401,657	68,585,737	63,011,995
vdm04_cost_prep_dom				25,550,356	21,902,320	17,574,705	14,179,622	15,220,068	16,955,328	18,335,578	17,612,465	16,181,156
vdm04_cost_dom				125,047,503	107,193,436	86,013,400	69,397,323	74,489,434	82,982,069	89,737,235	86,198,202	79,193,151
vdm04_cost_mining_exp				346,825,000	346,825,000	346,825,000	346,825,000	346,825,000	346,825,000	346,825,000	346,825,000	346,825,000
vdm04_cost_prep_exp				89,075,000	89,075,000	89,075,000	89,075,000	89,075,000	89,075,000	89,075,000	89,075,000	89,075,000
vdm04_cost_exp				435,900,000	435,900,000	435,900,000	435,900,000	435,900,000	435,900,000	435,900,000	435,900,000	435,900,000
vdm04_tot_cost				560,947,503	543,093,436	521,913,400	505,297,323	510,389,434	518,882,069	525,637,235	522,098,202	515,093,151
Mining costs - fixed	R	100,000,000		100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000
Processing costs - fixed	R	200,000,000		200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000
Logistic costs	R/ROMt	10		80,613,833	71,735,559	64,021,254	56,649,618	58,046,752	63,710,339	70,361,740	67,924,483	66,293,127
Total operating cash costs - excl. royalties				941,561,337	914,828,995	885,934,655	861,946,941	868,436,186	882,592,408	895,998,975	890,022,685	881,386,278
Royalties	%	3		67,405,900	66,348,499	65,094,117	64,110,035	64,411,614	64,914,588	65,314,660	65,105,062	64,690,190
Total operating cash cost	**R**			**1,008,967,237**	**981,177,494**	**951,028,772**	**926,056,977**	**932,847,800**	**947,506,995**	**961,313,635**	**955,127,747**	**946,076,468**
EBITDA				**1,237,896,104**	**1,230,439,125**	**1,218,775,141**	**1,210,944,199**	**1,214,206,000**	**1,216,312,594**	**1,215,841,710**	**1,215,040,993**	**1,210,263,206**
Depreciation - zero (contractor operation)	%	-	-	-	-	-	-	-	-	-	-	-
EBIT				**1,237,896,104**	**1,230,439,125**	**1,218,775,141**	**1,210,944,199**	**1,214,206,000**	**1,216,312,594**	**1,215,841,710**	**1,215,040,993**	**1,210,263,206**
Total CAPEX			**50,000,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	R	50,000,000	50,000,000	-	-	-	-	-	-	-	-	-
Sustainable CAPEX - zero (contractor operation)	R	-	-	-	-	-	-	-	-	-	-	-
DCF			**-50,000,000**	**724,894,115**	**649,123,798**	**579,252,621**	**518,496,194**	**468,371,906**	**422,688,749**	**380,653,251**	**342,705,013**	**307,529,214**
EBIT			-	1,237,896,104	1,230,439,125	1,218,775,141	1,210,944,199	1,214,206,000	1,216,312,594	1,215,841,710	1,215,040,993	1,210,263,206
-tax			-	433,263,637	430,653,694	426,571,299	423,830,470	424,972,100	425,709,408	425,544,598	425,264,348	423,592,122
+depreciation			-	-	-	-	-	-	-	-	-	-
-change in working capital												
-capex			50,000,000	-	-	-	-	-	-	-	-	-
Free cash flow			-50,000,000	804,632,468	799,785,431	792,203,842	787,113,730	789,233,900	790,603,186	790,297,111	789,776,646	786,671,084
Discount factor	%	11.00	1.00	0.90	0.81	0.73	0.66	0.59	0.53	0.48	0.43	0.39
Discounted free cash flow			-50,000,000	724,894,115	649,123,798	579,252,621	518,496,194	468,371,906	422,688,749	380,653,251	342,705,013	307,529,214
NPV	R	5,414,850,678										

VDM04 - NPV Scenario 01							
Year	**11**	**12**	**13**	**14**	**15**	**16**	**17**
sc_rom_cont	**6,612,518**	**6,502,698**	**6,215,190**	**5,596,900**	**5,525,541**	**55,870**	**-**
Total Revenue	**2,153,696,226**	**2,145,206,162**	**2,140,613,295**	**2,113,106,178**	**2,091,555,205**	**22,315,534**	**-**
revenue_prim	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	21,796,214	-
revenue_sec	153,696,226	145,206,163	140,613,294	113,106,178	91,555,205	519,320	-
revenue_total	2,153,696,226	2,145,206,162	2,140,613,295	2,113,106,178	2,091,555,205	22,315,534	-
Total operating cash cost	**944,490,193**	**938,836,682**	**933,497,325**	**912,555,601**	**900,278,941**	**306,241,707**	**-**
VDM04: Variable cost - mining and processing	513,754,124	509,453,522	507,127,025	493,193,420	482,276,873	5,013,544	-
vdm04_cost_mining_dom	61,946,565	58,524,684	56,673,549	45,586,931	36,900,909	209,309	-
vdm04_cost_prep_dom	15,907,559	15,028,838	14,553,476	11,706,489	9,475,964	53,750	-
vdm04_cost_dom	77,854,124	73,553,522	71,227,025	57,293,420	46,376,873	263,059	-
vdm04_cost_mining_exp	346,825,000	346,825,000	346,825,000	346,825,000	346,825,000	3,779,736	-
vdm04_cost_prep_exp	89,075,000	89,075,000	89,075,000	89,075,000	89,075,000	970,749	-
vdm04_cost_exp	435,900,000	435,900,000	435,900,000	435,900,000	435,900,000	4,750,485	-
vdm04_tot_cost	513,754,124	509,453,522	507,127,025	493,193,420	482,276,873	5,013,544	-
Mining costs - fixed	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	-
Processing costs - fixed	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	-
Logistic costs	66,125,182	65,026,976	62,151,901	55,968,995	55,255,412	558,697	-
Total operating cash costs - excl. royalties	879,879,306	874,480,498	869,278,926	849,162,415	837,532,285	305,572,241	-
Royalties	64,610,887	64,356,185	64,218,399	63,393,185	62,746,656	669,466	-
Total operating cash cost	**944,490,193**	**938,836,682**	**933,497,325**	**912,555,601**	**900,278,941**	**306,241,707**	**-**
EBITDA	**1,209,206,033**	**1,206,369,480**	**1,207,115,970**	**1,200,550,577**	**1,191,276,264**	**-283,926,173**	**-**
Depreciation - zero (contractor operation)	-	-	-	-	-	-	-
EBIT	**1,209,206,033**	**1,206,369,480**	**1,207,115,970**	**1,200,550,577**	**1,191,276,264**	**-283,926,173**	**-**
Total CAPEX	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	-	-	-	-	-	-	-
Sustainable CAPEX - zero (contractor operation)	-	-	-	-	-	-	-
DCF	**276,811,338**	**248,794,589**	**224,277,965**	**200,953,277**	**179,640,453**	**-59,341,804**	**-**
EBIT	1,209,206,033	1,206,369,480	1,207,115,970	1,200,550,577	1,191,276,264	-283,926,173	-
-tax	423,222,111	422,229,318	422,490,589	420,192,702	416,946,692	-	-
+depreciation	-	-	-	-	-	-	-
-change in working capital							
-capex	-	-	-	-	-	-	-
Free cash flow	785,983,921	784,140,162	784,625,380	780,357,875	774,329,572	-283,926,173	-
Discount factor	0.35	0.32	0.29	0.26	0.23	0.21	0.19
Discounted free cash flow	276,811,338	248,794,589	224,277,965	200,953,277	179,640,453	-59,341,804	-
NPV							

VDM04 - NPV Scenario 02												
Year			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Unit	**Value**										
sc_rom_cont				**8,061,383**	**7,173,556**	**6,402,125**	**5,664,962**	**5,804,675**	**6,371,034**	**7,036,174**	**6,792,448**	**6,629,313**
Total Revenue				**2,246,863,341**	**2,211,616,619**	**2,169,803,913**	**2,137,001,176**	**2,147,053,801**	**2,163,819,590**	**2,177,155,345**	**2,170,168,740**	**2,156,339,673**
revenue_prim				2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000
revenue_sec				246,863,341	211,616,619	169,803,913	137,001,176	147,053,801	163,819,590	177,155,345	170,168,740	156,339,673
revenue_total				2,246,863,341	2,211,616,619	2,169,803,913	2,137,001,176	2,147,053,801	2,163,819,590	2,177,155,345	2,170,168,740	2,156,339,673
Total operating cash cost				**1,308,439,319**	**1,728,550,056**	**1,895,543,858**	**1,953,168,762**	**2,154,057,905**	**2,149,645,248**	**1,848,059,772**	**1,624,924,123**	**1,589,971,457**
VDM04: Variable cost - mining and processing				860,419,586	1,290,465,999	1,466,428,486	1,532,409,109	1,731,599,539	1,721,020,321	1,412,383,371	1,191,894,578	1,158,988,140
vdm04_tot_cost				860,419,586	1,290,465,999	1,466,428,486	1,532,409,109	1,731,599,539	1,721,020,321	1,412,383,371	1,191,894,578	1,158,988,140
Mining costs - fixed	R	100,000,000		100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000
Processing costs - fixed	R	200,000,000		200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000
Logistic costs	R/ROMt	10		80,613,833	71,735,559	64,021,254	56,649,618	58,046,752	63,710,339	70,361,740	67,924,483	66,293,127
Total operating cash costs - excl. royalties				1,241,033,419	1,662,201,558	1,830,449,740	1,889,058,727	2,089,646,291	2,084,730,660	1,782,745,111	1,559,819,061	1,525,281,267
Royalties	%	3		67,405,900	66,348,499	65,094,117	64,110,035	64,411,614	64,914,588	65,314,660	65,105,062	64,690,190
Total operating cash cost	**R**			**1,308,439,319**	**1,728,550,056**	**1,895,543,858**	**1,953,168,762**	**2,154,057,905**	**2,149,645,248**	**1,848,059,772**	**1,624,924,123**	**1,589,971,457**
EBITDA				**938,424,022**	**483,066,562**	**274,260,056**	**183,832,414**	**-7,004,104**	**14,174,342**	**329,095,574**	**545,244,617**	**566,368,216**
Depreciation - zero (contractor operation)	%	-	-	-	-	-	-	-	-	-	-	-
EBIT				**938,424,022**	**483,066,562**	**274,260,056**	**183,832,414**	**-7,004,104**	**14,174,342**	**329,095,574**	**545,244,617**	**566,368,216**
Total CAPEX			**50,000,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	R	50,000,000	50,000,000	-	-	-	-	-	-	-	-	-
Sustainable CAPEX - zero (contractor operation)	R	-	-	-	-	-	-	-	-	-	-	-
DCF			**-50,000,000**	**549,527,581**	**254,843,978**	**130,348,783**	**78,712,468**	**-4,156,595**	**4,925,818**	**103,032,573**	**153,787,456**	**143,914,788**
EBIT			-	938,424,022	483,066,562	274,260,056	183,832,414	-7,004,104	14,174,342	329,095,574	545,244,617	566,368,216
-tax			-	328,448,408	169,073,297	95,991,019	64,341,345	-	4,961,020	115,183,451	190,835,616	198,228,876
+depreciation			-	-	-	-	-	-	-	-	-	-
-change in working capital												
-capex			50,000,000	-	-	-	-	-	-	-	-	-
Free cash flow			-50,000,000	609,975,614	313,993,266	178,269,036	119,491,069	-7,004,104	9,213,322	213,912,123	354,409,001	368,139,341
Discount factor	%	11.00	1.00	0.90	0.81	0.73	0.66	0.59	0.53	0.48	0.43	0.39
Discounted free cash flow			-50,000,000	549,527,581	254,843,978	130,348,783	78,712,468	-4,156,595	4,925,818	103,032,573	153,787,456	143,914,788
NPV	R	2,148,766,446										

VDM04 - NPV Scenario 02							
Year	**11**	**12**	**13**	**14**	**15**	**16**	**17**
sc_rom_cont	**6,612,518**	**6,502,698**	**6,215,190**	**5,596,900**	**5,525,541**	**55,870**	**-**
Total Revenue	**2,153,696,226**	**2,145,206,162**	**2,140,613,295**	**2,113,106,178**	**2,091,555,205**	**22,315,534**	**-**
revenue_prim	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	21,796,214	-
revenue_sec	153,696,226	145,206,163	140,613,294	113,106,178	91,555,205	519,320	-
revenue_total	2,153,696,226	2,145,206,162	2,140,613,295	2,113,106,178	2,091,555,205	22,315,534	-
Total operating cash cost	**1,473,187,059**	**1,336,621,669**	**1,171,712,813**	**1,076,508,139**	**982,101,560**	**307,193,211**	**-**
VDM04: Variable cost - mining and processing	1,042,450,991	907,238,508	745,342,514	657,145,959	564,099,492	5,965,048	-
vdm04_tot_cost	1,042,450,991	907,238,508	745,342,514	657,145,959	564,099,492	5,965,048	-
Mining costs - fixed	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	-
Processing costs - fixed	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	-
Logistic costs	66,125,182	65,026,976	62,151,901	55,968,995	55,255,412	558,697	-
Total operating cash costs - excl. royalties	1,408,576,172	1,272,265,484	1,107,494,414	1,013,114,954	919,354,904	306,523,745	-
Royalties	64,610,887	64,356,185	64,218,399	63,393,185	62,746,656	669,466	-
Total operating cash cost	**1,473,187,059**	**1,336,621,669**	**1,171,712,813**	**1,076,508,139**	**982,101,560**	**307,193,211**	**-**
EBITDA	**680,509,166**	**808,584,494**	**968,900,481**	**1,036,598,039**	**1,109,453,645**	**-284,877,677**	**-**
Depreciation - zero (contractor operation)	-	-	-	-	-	-	-
EBIT	**680,509,166**	**808,584,494**	**968,900,481**	**1,036,598,039**	**1,109,453,645**	**-284,877,677**	**-**
Total CAPEX	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	-	-	-	-	-	-	-
Sustainable CAPEX - zero (contractor operation)	-	-	-	-	-	-	-
DCF	**155,782,098**	**166,757,739**	**180,018,353**	**173,510,202**	**167,301,878**	**-59,540,673**	**-**
EBIT	680,509,166	808,584,494	968,900,481	1,036,598,039	1,109,453,645	-284,877,677	-
-tax	238,178,208	283,004,573	339,115,168	362,809,313	388,308,776	-	-
+depreciation	-	-	-	-	-	-	-
-change in working capital							
-capex	-	-	-	-	-	-	-
Free cash flow	442,330,958	525,579,921	629,785,313	673,788,725	721,144,869	-284,877,677	-
Discount factor	0.35	0.32	0.29	0.26	0.23	0.21	0.19
Discounted free cash flow	155,782,098	166,757,739	180,018,353	173,510,202	167,301,878	-59,540,673	-
NPV							

APPENDIX E: VDM 05 SCENARIO 01 AND SCENARIO 02 NPV CALCULATIONS

VDM05 - NPV Scenario 01												
Year			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Unit	**Value**										
sc_rom_cont				**8,061,383**	**7,173,556**	**6,402,125**	**5,664,962**	**5,804,675**	**6,371,034**	**7,036,174**	**6,792,448**	**6,629,313**
Total Revenue				**2,246,863,341**	**2,211,616,619**	**2,169,803,913**	**2,137,001,176**	**2,147,053,801**	**2,163,819,590**	**2,177,155,345**	**2,170,168,740**	**2,156,339,673**
revenue_prim				2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000
revenue_sec				246,863,341	211,616,619	169,803,913	137,001,176	147,053,801	163,819,590	177,155,345	170,168,740	156,339,673
revenue_total				2,246,863,341	2,211,616,619	2,169,803,913	2,137,001,176	2,147,053,801	2,163,819,590	2,177,155,345	2,170,168,740	2,156,339,673
Total operating cash cost				**967,791,958**	**934,865,806**	**898,623,833**	**868,871,784**	**877,127,550**	**894,229,977**	**909,980,001**	**902,775,973**	**891,709,422**
VDM05: Variable cost - mining and processing				519,772,225	496,781,749	469,508,462	448,112,131	454,669,184	465,605,051	474,303,600	469,746,428	460,726,105
vdm05_cost_mining				413,572,074	395,279,025	373,578,231	356,553,610	361,770,923	370,472,367	377,393,624	373,767,576	366,590,290
vdm05_cost_prep				106,200,151	101,502,724	95,930,231	91,558,520	92,898,261	95,132,684	96,909,976	95,978,852	94,135,815
vdm05_cost				519,772,225	496,781,749	469,508,462	448,112,131	454,669,184	465,605,051	474,303,600	469,746,428	460,726,105
Mining costs - fixed	R	100,000,000		100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000
Processing costs - fixed	R	200,000,000		200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000
Logistic costs	R/ROMt	10		80,613,833	71,735,559	64,021,254	56,649,618	58,046,752	63,710,339	70,361,740	67,924,483	66,293,127
Total operating cash costs - excl. royalties				900,386,058	868,517,308	833,529,716	804,761,749	812,715,936	829,315,390	844,665,340	837,670,911	827,019,232
Royalties	%	3		67,405,900	66,348,499	65,094,117	64,110,035	64,411,614	64,914,588	65,314,660	65,105,062	64,690,190
Total operating cash cost	**R**			**967,791,958**	**934,865,806**	**898,623,833**	**868,871,784**	**877,127,550**	**894,229,977**	**909,980,001**	**902,775,973**	**891,709,422**
EBITDA				**1,279,071,383**	**1,276,750,812**	**1,271,180,080**	**1,268,129,392**	**1,269,926,251**	**1,269,589,612**	**1,267,175,345**	**1,267,392,767**	**1,264,630,251**
Depreciation - zero (contractor operation)	%	-	-	-	-	-	-	-	-	-	-	-
EBIT				**1,279,071,383**	**1,276,750,812**	**1,271,180,080**	**1,268,129,392**	**1,269,926,251**	**1,269,589,612**	**1,267,175,345**	**1,267,392,767**	**1,264,630,251**
Total CAPEX			**50,000,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	R	50,000,000	50,000,000	-	-	-	-	-	-	-	-	-
Sustainable CAPEX - zero (contractor operation)	R	-	-	-	-	-	-	-	-	-	-	-
DCF			**-50,000,000**	**749,005,765**	**673,555,741**	**604,159,347**	**542,981,471**	**489,865,623**	**441,203,394**	**396,724,681**	**357,470,947**	**321,343,940**
EBIT			-	1,279,071,383	1,276,750,812	1,271,180,080	1,268,129,392	1,269,926,251	1,269,589,612	1,267,175,345	1,267,392,767	1,264,630,251
-tax			-	447,674,984	446,862,784	444,913,028	443,845,287	444,474,188	444,356,364	443,511,371	443,587,468	442,620,588
+depreciation			-	-	-	-	-	-	-	-	-	-
-change in working capital												
-capex			50,000,000	-	-	-	-	-	-	-	-	-
Free cash flow			-50,000,000	831,396,399	829,888,028	826,267,052	824,284,105	825,452,063	825,233,248	823,663,974	823,805,299	822,009,663
Discount factor	%	11.00	1.00	0.90	0.81	0.73	0.66	0.59	0.53	0.48	0.43	0.39
Discounted free cash flow			-50,000,000	749,005,765	673,555,741	604,159,347	542,981,471	489,865,623	441,203,394	396,724,681	357,470,947	321,343,940
NPV	R	5,651,991,257										

VDM05 - NPV Scenario 01							
Year	**11**	**12**	**13**	**14**	**15**	**16**	**17**
sc_rom_cont	**6,612,518**	**6,502,698**	**6,215,190**	**5,596,900**	**5,525,541**	**55,870**	**-**
Total Revenue	**2,153,696,226**	**2,145,206,162**	**2,140,613,295**	**2,113,106,178**	**2,091,555,205**	**22,315,534**	**-**
revenue_prim	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	21,796,214	-
revenue_sec	153,696,226	145,206,163	140,613,294	113,106,178	91,555,205	519,320	-
revenue_total	2,153,696,226	2,145,206,162	2,140,613,295	2,113,106,178	2,091,555,205	22,315,534	-
Total operating cash cost	**889,737,925**	**882,847,181**	**876,838,517**	**851,888,255**	**836,471,032**	**305,476,597**	**-**
VDM05: Variable cost - mining and processing	459,001,856	453,464,020	450,468,217	432,526,075	418,468,964	4,248,434	-
vdm05_cost_mining	365,218,341	360,811,998	358,428,300	344,152,106	332,967,152	3,380,392	-
vdm05_cost_prep	93,783,515	92,652,021	92,039,917	88,373,969	85,501,812	868,042	-
vdm05_cost	459,001,856	453,464,020	450,468,217	432,526,075	418,468,964	4,248,434	-
Mining costs - fixed	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	-
Processing costs - fixed	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	-
Logistic costs	66,125,182	65,026,976	62,151,901	55,968,995	55,255,412	558,697	-
Total operating cash costs - excl. royalties	825,127,038	818,490,996	812,620,118	788,495,070	773,724,375	304,807,131	-
Royalties	64,610,887	64,356,185	64,218,399	63,393,185	62,746,656	669,466	-
Total operating cash cost	**889,737,925**	**882,847,181**	**876,838,517**	**851,888,255**	**836,471,032**	**305,476,597**	**-**
EBITDA	**1,263,958,301**	**1,262,358,982**	**1,263,774,778**	**1,261,217,922**	**1,255,084,174**	**-283,161,063**	**-**
Depreciation - zero (contractor operation)	-	-	-	-	-	-	-
EBIT	**1,263,958,301**	**1,262,358,982**	**1,263,774,778**	**1,261,217,922**	**1,255,084,174**	**-283,161,063**	**-**
Total CAPEX	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	-	-	-	-	-	-	-
Sustainable CAPEX - zero (contractor operation)	-	-	-	-	-	-	-
DCF	**289,345,222**	**260,341,537**	**234,804,975**	**211,108,036**	**189,262,471**	**-59,181,893**	**-**
EBIT	1,263,958,301	1,262,358,982	1,263,774,778	1,261,217,922	1,255,084,174	-283,161,063	-
-tax	442,385,405	441,825,644	442,321,172	441,426,273	439,279,461	-	-
+depreciation	-	-	-	-	-	-	-
-change in working capital							
-capex	-	-	-	-	-	-	-
Free cash flow	821,572,896	820,533,338	821,453,606	819,791,649	815,804,713	-283,161,063	-
Discount factor	0.35	0.32	0.29	0.26	0.23	0.21	0.19
Discounted free cash flow	289,345,222	260,341,537	234,804,975	211,108,036	189,262,471	-59,181,893	-
NPV							

VDM05 - NPV Scenario 02												
Year			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Unit	**Value**										
sc_rom_cont				**8,061,383**	**7,173,556**	**6,402,125**	**5,664,962**	**5,804,675**	**6,371,034**	**7,036,174**	**6,792,448**	**6,629,313**
Total Revenue				**2,246,863,341**	**2,211,616,619**	**2,169,803,913**	**2,137,001,176**	**2,147,053,801**	**2,163,819,590**	**2,177,155,345**	**2,170,168,740**	**2,156,339,673**
revenue_prim				2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000
revenue_sec				246,863,341	211,616,619	169,803,913	137,001,176	147,053,801	163,819,590	177,155,345	170,168,740	156,339,673
revenue_total				2,246,863,341	2,211,616,619	2,169,803,913	2,137,001,176	2,147,053,801	2,163,819,590	2,177,155,345	2,170,168,740	2,156,339,673
Total operating cash cost				**1,308,439,319**	**1,728,550,056**	**1,895,543,858**	**1,953,168,762**	**2,154,057,905**	**2,149,645,248**	**1,848,059,772**	**1,624,924,123**	**1,589,971,457**
VDM05: Variable cost - mining and processing				860,419,586	1,290,465,999	1,466,428,486	1,532,409,109	1,731,599,539	1,721,020,321	1,412,383,371	1,191,894,578	1,158,988,140
vdm05_cost				860,419,586	1,290,465,999	1,466,428,486	1,532,409,109	1,731,599,539	1,721,020,321	1,412,383,371	1,191,894,578	1,158,988,140
Mining costs - fixed	R	100,000,000		100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000
Processing costs - fixed	R	200,000,000		200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000
Logistic costs	R/ROMt	10		80,613,833	71,735,559	64,021,254	56,649,618	58,046,752	63,710,339	70,361,740	67,924,483	66,293,127
Total operating cash costs - excl. royalties				1,241,033,419	1,662,201,558	1,830,449,740	1,889,058,727	2,089,646,291	2,084,730,660	1,782,745,111	1,559,819,061	1,525,281,267
Royalties	%	3		67,405,900	66,348,499	65,094,117	64,110,035	64,411,614	64,914,588	65,314,660	65,105,062	64,690,190
Total operating cash cost	**R**			**1,308,439,319**	**1,728,550,056**	**1,895,543,858**	**1,953,168,762**	**2,154,057,905**	**2,149,645,248**	**1,848,059,772**	**1,624,924,123**	**1,589,971,457**
EBITDA				**938,424,022**	**483,066,562**	**274,260,056**	**183,832,414**	**-7,004,104**	**14,174,342**	**329,095,574**	**545,244,617**	**566,368,216**
Depreciation - zero (contractor operation)	%	-	-	-	-	-	-	-	-	-	-	-
EBIT				**938,424,022**	**483,066,562**	**274,260,056**	**183,832,414**	**-7,004,104**	**14,174,342**	**329,095,574**	**545,244,617**	**566,368,216**
Total CAPEX			**50,000,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	R	50,000,000	50,000,000	-	-	-	-	-	-	-	-	-
Sustainable CAPEX - zero (contractor operation)	R	-	-	-	-	-	-	-	-	-	-	-
DCF			**-50,000,000**	**549,527,581**	**254,843,978**	**130,348,783**	**78,712,468**	**-4,156,595**	**4,925,818**	**103,032,573**	**153,787,456**	**143,914,788**
EBIT			-	938,424,022	483,066,562	274,260,056	183,832,414	-7,004,104	14,174,342	329,095,574	545,244,617	566,368,216
-tax			-	328,448,408	169,073,297	95,991,019	64,341,345	-	4,961,020	115,183,451	190,835,616	198,228,876
+depreciation			-	-	-	-	-	-	-	-	-	-
-change in working capital												
-capex			50,000,000	-	-	-	-	-	-	-	-	-
Free cash flow			-50,000,000	609,975,614	313,993,266	178,269,036	119,491,069	-7,004,104	9,213,322	213,912,123	354,409,001	368,139,341
Discount factor	%	11.00	1.00	0.90	0.81	0.73	0.66	0.59	0.53	0.48	0.43	0.39
Discounted free cash flow			-50,000,000	549,527,581	254,843,978	130,348,783	78,712,468	-4,156,595	4,925,818	103,032,573	153,787,456	143,914,788
NPV	R	2,148,766,446										

VDM05 - NPV Scenario 02							
Year	**11**	**12**	**13**	**14**	**15**	**16**	**17**
sc_rom_cont	**6,612,518**	**6,502,698**	**6,215,190**	**5,596,900**	**5,525,541**	**55,870**	**-**
Total Revenue	**2,153,696,226**	**2,145,206,162**	**2,140,613,295**	**2,113,106,178**	**2,091,555,205**	**22,315,534**	**-**
revenue_prim	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	21,796,214	-
revenue_sec	153,696,226	145,206,163	140,613,294	113,106,178	91,555,205	519,320	-
revenue_total	2,153,696,226	2,145,206,162	2,140,613,295	2,113,106,178	2,091,555,205	22,315,534	-
Total operating cash cost	**1,473,187,059**	**1,336,621,669**	**1,171,712,813**	**1,076,508,139**	**982,101,560**	**307,193,211**	**-**
VDM05: Variable cost - mining and processing	1,042,450,991	907,238,508	745,342,514	657,145,959	564,099,492	5,965,048	-
vdm05_cost	1,042,450,991	907,238,508	745,342,514	657,145,959	564,099,492	5,965,048	-
Mining costs - fixed	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	-
Processing costs - fixed	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	-
Logistic costs	66,125,182	65,026,976	62,151,901	55,968,995	55,255,412	558,697	-
Total operating cash costs - excl. royalties	1,408,576,172	1,272,265,484	1,107,494,414	1,013,114,954	919,354,904	306,523,745	-
Royalties	64,610,887	64,356,185	64,218,399	63,393,185	62,746,656	669,466	-
Total operating cash cost	**1,473,187,059**	**1,336,621,669**	**1,171,712,813**	**1,076,508,139**	**982,101,560**	**307,193,211**	**-**
EBITDA	**680,509,166**	**808,584,494**	**968,900,481**	**1,036,598,039**	**1,109,453,645**	**-284,877,677**	**-**
Depreciation - zero (contractor operation)	-	-	-	-	-	-	-
EBIT	**680,509,166**	**808,584,494**	**968,900,481**	**1,036,598,039**	**1,109,453,645**	**-284,877,677**	**-**
Total CAPEX	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	-	-	-	-	-	-	-
Sustainable CAPEX - zero (contractor operation)	-	-	-	-	-	-	-
DCF	**155,782,098**	**166,757,739**	**180,018,353**	**173,510,202**	**167,301,878**	**-59,540,673**	**-**
EBIT	680,509,166	808,584,494	968,900,481	1,036,598,039	1,109,453,645	-284,877,677	-
-tax	238,178,208	283,004,573	339,115,168	362,809,313	388,308,776	-	-
+depreciation	-	-	-	-	-	-	-
-change in working capital							
-capex	-	-	-	-	-	-	-
Free cash flow	442,330,958	525,579,921	629,785,313	673,788,725	721,144,869	-284,877,677	-
Discount factor	0.35	0.32	0.29	0.26	0.23	0.21	0.19
Discounted free cash flow	155,782,098	166,757,739	180,018,353	173,510,202	167,301,878	-59,540,673	-
NPV							

APPENDIX F: VDM 06 SCENARIO 01 AND SCENARIO 02 NPV CALCULATIONS

VDM06 - NPV Scenario 01												
Year			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Unit	**Value**										
sc_rom_cont				**7,628,043**	**7,592,734**	**7,122,747**	**7,548,432**	**7,771,622**	**6,788,720**	**5,767,031**	**5,031,854**	**-**
Total Revenue				**2,235,235,368**	**2,236,641,244**	**2,180,815,456**	**2,196,190,415**	**2,204,065,820**	**2,166,649,505**	**2,125,693,397**	**1,904,028,814**	**-**
revenue_prim				2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	1,821,907,203	-
revenue_sec				235,235,368	236,641,244	180,815,456	196,190,415	204,065,820	166,649,505	125,693,397	82,121,611	-
revenue_total				2,235,235,368	2,236,641,244	2,180,815,456	2,196,190,415	2,204,065,820	2,166,649,505	2,125,693,397	1,904,028,814	-
Total operating cash cost				**1,434,320,370**	**1,318,748,382**	**1,288,216,935**	**1,224,388,056**	**1,128,443,089**	**1,031,477,967**	**947,062,818**	**885,164,054**	**-**
VDM06: Variable cost - mining and processing				990,982,883	875,721,808	851,565,001	783,018,021	684,604,895	598,591,286	525,621,706	477,724,652	-
vdm06_cost_mining				57,362,880	57,097,357	53,563,058	56,764,210	58,442,597	51,051,171	43,368,073	37,839,540	-
vdm06_cost_proc				137,915,010	137,276,625	128,779,266	136,475,654	140,510,924	122,740,050	104,267,921	90,975,915	-
vdm06_cost				990,982,883	875,721,808	851,565,001	783,018,021	684,604,895	598,591,286	525,621,706	477,724,652	-
Mining costs - fixed	R	100,000,000		100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	-
Processing costs - fixed	R	200,000,000		200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	-
Logistic costs	R/ROMt	10		76,280,426	75,927,337	71,227,470	75,484,322	77,716,219	67,887,196	57,670,310	50,318,537	-
Total operating cash costs - excl. royalties				1,367,263,309	1,251,649,145	1,222,792,472	1,158,502,343	1,062,321,114	966,478,482	883,292,016	828,043,190	-
Royalties	%	3		67,057,061	67,099,237	65,424,464	65,885,712	66,121,975	64,999,485	63,770,802	57,120,864	-
Total operating cash cost	**R**			**1,434,320,370**	**1,318,748,382**	**1,288,216,935**	**1,224,388,056**	**1,128,443,089**	**1,031,477,967**	**947,062,818**	**885,164,054**	**-**
EBITDA				**800,914,999**	**917,892,862**	**892,598,521**	**971,802,359**	**1,075,622,731**	**1,135,171,538**	**1,178,630,579**	**1,018,864,760**	**-**
Depreciation - zero (contractor operation)	%	-	-	-	-	-	-	-	-	-	-	-
EBIT				**800,914,999**	**917,892,862**	**892,598,521**	**971,802,359**	**1,075,622,731**	**1,135,171,538**	**1,178,630,579**	**1,018,864,760**	**-**
Total CAPEX			**50,000,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	R	50,000,000	50,000,000	-	-	-	-	-	-	-	-	-
Sustainable CAPEX - zero (contractor operation)	R	-	-	-	-	-	-	-	-	-	-	-
DCF			**-50,000,000**	**469,004,278**	**484,238,585**	**424,229,225**	**416,101,605**	**414,914,330**	**394,490,889**	**369,003,266**	**287,373,070**	**-**
EBIT			-	800,914,999	917,892,862	892,598,521	971,802,359	1,075,622,731	1,135,171,538	1,178,630,579	1,018,864,760	-
-tax			-	280,320,250	321,262,502	312,409,482	340,130,826	376,467,956	397,310,038	412,520,703	356,602,666	-
+depreciation			-	-	-	-	-	-	-	-	-	-
-change in working capital												
-capex			50,000,000	-	-	-	-	-	-	-	-	-
Free cash flow			-50,000,000	520,594,749	596,630,360	580,189,039	631,671,534	699,154,775	737,861,500	766,109,876	662,262,094	-
Discount factor	%	11.00	1.00	0.90	0.81	0.73	0.66	0.59	0.53	0.48	0.43	0.39
Discounted free cash flow			-50,000,000	469,004,278	484,238,585	424,229,225	416,101,605	414,914,330	394,490,889	369,003,266	287,373,070	-
NPV	R	3,209,355,247										

VDM06 - NPV Scenario 02												
Year			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
	Unit	**Value**										
sc_rom_cont				**7,628,043**	**7,592,734**	**7,122,747**	**7,548,432**	**7,771,622**	**6,788,720**	**5,767,031**	**5,031,854**	**-**
Total Revenue				**2,235,235,368**	**2,236,641,244**	**2,180,815,456**	**2,196,190,415**	**2,204,065,820**	**2,166,649,505**	**2,125,693,397**	**1,904,028,814**	**-**
revenue_prim				2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	2,000,000,000	1,821,907,203	-
revenue_sec				235,235,368	236,641,244	180,815,456	196,190,415	204,065,820	166,649,505	125,693,397	82,121,611	-
revenue_total				2,235,235,368	2,236,641,244	2,180,815,456	2,196,190,415	2,204,065,820	2,166,649,505	2,125,693,397	1,904,028,814	-
Total operating cash cost				**1,246,434,296**	**1,226,810,309**	**1,182,783,845**	**1,175,583,571**	**1,123,372,732**	**1,038,854,375**	**954,762,261**	**894,119,825**	**-**
VDM06: Variable cost - mining and processing				803,096,809	783,783,735	746,131,911	734,213,537	679,534,539	605,967,694	533,321,149	486,680,423	-
vdm06_cost				803,096,809	783,783,735	746,131,911	734,213,537	679,534,539	605,967,694	533,321,149	486,680,423	-
Mining costs - fixed	R	100,000,000		100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	100,000,000	-
Processing costs - fixed	R	200,000,000		200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	200,000,000	-
Logistic costs	R/ROMt	10		76,280,426	75,927,337	71,227,470	75,484,322	77,716,219	67,887,196	57,670,310	50,318,537	-
Total operating cash costs - excl. royalties				1,179,377,235	1,159,711,072	1,117,359,381	1,109,697,859	1,057,250,758	973,854,890	890,991,459	836,998,961	-
Royalties	%	3		67,057,061	67,099,237	65,424,464	65,885,712	66,121,975	64,999,485	63,770,802	57,120,864	-
Total operating cash cost	**R**			**1,246,434,296**	**1,226,810,309**	**1,182,783,845**	**1,175,583,571**	**1,123,372,732**	**1,038,854,375**	**954,762,261**	**894,119,825**	**-**
EBITDA				**988,801,072**	**1,009,830,935**	**998,031,612**	**1,020,606,844**	**1,080,693,087**	**1,127,795,130**	**1,170,931,135**	**1,009,908,989**	**-**
Depreciation - zero (contractor operation)	%	-	-	-	-	-	-	-	-	-	-	-
EBIT				**988,801,072**	**1,009,830,935**	**998,031,612**	**1,020,606,844**	**1,080,693,087**	**1,127,795,130**	**1,170,931,135**	**1,009,908,989**	**-**
Total CAPEX			**50,000,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Infrastructure	R	50,000,000	50,000,000	-	-	-	-	-	-	-	-	-
Sustainable CAPEX - zero (contractor operation)	R	-	-	-	-	-	-	-	-	-	-	-
DCF			**-50,000,000**	**579,027,655**	**532,740,937**	**474,338,873**	**436,998,471**	**416,870,186**	**391,927,465**	**366,592,739**	**284,847,075**	**-**
EBIT			-	988,801,072	1,009,830,935	998,031,612	1,020,606,844	1,080,693,087	1,127,795,130	1,170,931,135	1,009,908,989	-
-tax			-	346,080,375	353,440,827	349,311,064	357,212,395	378,242,581	394,728,295	409,825,897	353,468,146	-
+depreciation			-	-	-	-	-	-	-	-	-	-
-change in working capital												
-capex			50,000,000	-	-	-	-	-	-	-	-	-
Free cash flow			-50,000,000	642,720,697	656,390,108	648,720,548	663,394,448	702,450,507	733,066,834	761,105,238	656,440,843	-
Discount factor	%	11.00	1.00	0.90	0.81	0.73	0.66	0.59	0.53	0.48	0.43	0.39
Discounted free cash flow			-50,000,000	579,027,655	532,740,937	474,338,873	436,998,471	416,870,186	391,927,465	366,592,739	284,847,075	-
NPV	R	3,433,343,402										